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THE NEW PERSPECTIVE IN THE HALOPHYTES

By V. J. CHAPMAN

I. INTRODUCTION

A SUMMARY of the recent literature on the halophytes appeared in the *Botanical Review* for 1941 (Uphof), but it would seem that there is still need for a critical discussion of the more important recent papers, some of which have appeared since the review referred to above. The object of such a discussion would be first, the assessment of those phases in which progress has been most pronounced, and second, an indication of the direction along which future research might profitably proceed.

Stocker (1928) has defined halophytes as "those plants which at any stage of their life are subjected to a concentration of salt [*Salzwirkung*, in the original] which is more than 'normal' glycophytic plants can bear without dying." (Glycophyte is a convenient term for all plants that cannot grow in places where the concentration of sodium chloride in the soil solution is more than 0.5 per cent. It must be understood that this is a purely arbitrary definition.) While it may be easy to distinguish between extreme halophytes and glycophytes it is by no means so easy to determine to which class a plant should belong at the lower concentrations of sodium chloride. Field observations and experimental work indicate that the boundary should be placed at about 0.5 per cent sodium chloride in the soil water. Among plants there appears to be a marked difference in tolerance above and below this concentration.

At this point it is essential to define the terms that it is proposed to employ subsequently.

Halophyte. A general term which includes all plants that are capable of growing in an environment where there is more than 0.5 per cent sodium chloride. Its use will not imply that the species is either common or rare in such habitats nor will the term involve the assumption that a plant cannot grow under any other conditions. The Halophytes will not include plants that grow in places where the soil is characterized by an excess of a salt other than sodium chloride, e.g. inland areas where there is an excess of magnesium salts, etc. The flora of such places should be distinguished from halophytes, as defined above, and the plants should be placed in another category. In the past they have commonly been included in the halophytes.

Euhalophyte. This term will be restricted to those plants whose optimal growth takes place in an environment in which there is more than 0.5 per cent sodium chloride. (It is impossible to define more accurately the term "optimal growth." We cannot say growth to maturity because plants may flower and set seed and yet be weakly or stunted. Whilst field observations may indicate whether growth is approaching optimum or not, experiment must ultimately be the decisive factor.) Euhalophytes will not grow unless there is an abnormal concentration of sodium chloride in the habitat. This class includes species of *Salicornia*, *Rhizophora*, and the 'submerged' halophytes, e.g. *Zostera*, *Cymodocea*, *Posidonia*.

Miohalophyte. This will be applied to those plants which are to be found, either commonly or rarely, in habitats where there is more than 0.5 per cent sodium chloride; their optimal development occurs, either naturally or experimentally, in an

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environment where there is less than 0.5 per cent sodium chloride (cf. below).

It must be admitted that in many cases we do not yet know whether a species is an eu- or miohalophyte; for such plants we must therefore use the non-committal term of halophyte. In 1939, Van Eijk suggested that what I call miohalophytes could be divided into two classes.

a) Plants which normally grow under glycophytic conditions but which nevertheless have some resistance to a concentration of more than 0.5 per cent sodium chloride. The evidence is based either upon growth in culture solutions or else upon records of occasional plants growing in a halophytic environment. This group can be termed the *haloglycophytes*, and then the true *miohalophytes* will form the second group.

b) Plants which normally grow on haline soils, but whose optimal development is under glycophytic conditions. This category includes a very large number of plants that grow around sea shores, e.g. *Aster Tripolium*, *A. subulatus*, *Triglochin maritimum*, *Plantago maritima*, *P. oliganthos*.

The evidence which is slowly accumulating suggests that the large majority of halophytes are really miohalophytes and that the euhalophytes form a relatively small class. One of the most important results of recent experimental work has been to show that halophytes grow as well, or often even better, under purely glycophytic conditions. The submerged marine phanerogams, together with one or two genera such as *Salicornia* and *Arthrocnemon*, form the bulk of the euhalophytes. A large number of the miohalophytes occur in haline areas because they are unable to compete successfully with glycophytes in non-haline areas. Anyone who attempts to grow miohalophytes under both haline and glycophytic conditions cannot help but observe that the plants are relatively slow growing as compared with the majority of glycophytes: this is true not only of the herbaceous species but also of the woody ones. Serious competition between species only occurs under glycophytic conditions because when there is more than 0.5 per cent sodium chloride present the glycophytes do not grow. Germination may be excellent and rapid, e.g. *Aster* spp., *Salicornia* spp., and even early seedling growth may be good, e.g. *Rhizophora*, *Avicennia*, but it is not long before the growth rate slows down, and under glycophytic conditions the halophytes are soon surpassed and crowded out by other species. In fact halophytes can only be grown successfully under such conditions so long as they are kept free from competition. This phenomenon may also be correlated to a very large extent with the fact that most of the halophytes are perennials.

There is, however, a further complication. There are those plants which grow on sand dunes near the sea shore: the roots of such plants will commonly be in fresh water, since Oliver (1924), Hill and Hanley (1914) and Chapman (1937) have all demonstrated the presence of a fresh-water table in maritime dunes. The surface of the sand, however, may contain some salt from spray, and the aerial portions of the plants will also be subjected to spray in stormy weather. Stocker (1928) has suggested that the term *xero-halophyte* should be reserved for the plants of the salt (sodium chloride) desert, and that the term *aero-halophyte* should be employed for plants that are subjected to salt in the form of either spray or powder. Schratz (1934), on the other hand, regarded the dunes as xero-haline in contrast to the *hygro-haline* habitat where there is a salt-water table. Examples of plants growing on the former are *Arenaria peploides*, *Psamma arenaria*, *Eryngium maritimum*, and in the latter any of the salt marsh plants, e.g. *Limonium vulgare*, *Triglochin maritimum*, *Spergularia marginata*, etc. There would seem, however, to be no reason for departing from Stocker's earlier usage of these terms.

The degree of salt which a plant is able to withstand has been used by Iversen (1936) as a basis for a classification of salt marsh plants, and by widening the scope it could well be employed for the halophytes as a whole. In many respects it is more convenient because it is dependent upon a feature which can be measured in the field; van Eijk's two classes (cf. above), on the other hand, are dependent upon a knowledge of the growth conditions of the plant, and it cannot be said that adequate studies have been made of many species. Iversen's schema is based upon the amount of sodium chloride present in the soil water table, but since the roots of many plants do not reach down to this depth a more satisfactory criterion would be the percentage of Cl^- present in the soil water at the absorbing region. This classification will include plants from any habitat; furthermore, allowance can be made for seasonal changes in the environment (annual range) and this is an additional feature in favor of the scheme. On this schema,

which has been modified somewhat from the original, there are five groups:

Miohalophytes

1. *Glyco-mesohalophytes.* Plants that grow in habitats with a range of 0.01–1.0 per cent sodium chloride.
2. *Euryhalophytes.* Plants that grow in habitats with a range of 0.1 <1.0 per cent sodium chloride.

Euhalophytes

3. *Mesohalophytes.* Plants that grow in habitats with a range of 0.5–1.0 per cent sodium chloride.
4. *Meso-euhalophytes.* Plants that grow in habitats with a range of 0.5– <1.0 per cent sodium chloride.
5. *Euhalophytes.* Plants that grow in habitats with more than 1.0 per cent sodium chloride. (The term is not used again in this sense.)

Summarizing we can say that the term 'euhalophyte' should be restricted to those plants that can grow or reach their optimal development only so long as there is more than 0.5 per cent sodium chloride present, e.g. the meso-, meso-eu- and euhalophytes of the scheme above. All other plants which commonly grow under haline conditions, but which reach their optimal development in a fresh-water environment are to be regarded as *miohalophytes*. The terms hygrohalophyte, xerohalophyte and aerohalophyte may remain in use purely as a means of distinguishing groups of plants that commonly grow under certain ecological conditions.

II. SUCCULENCE

A characteristic of a large number of halophytes is the abnormal development of parenchymatous tissue which brings about the appearance known as succulence. (Parenchymatous tissue has been called internal water storage tissue, and it develops from the hypodermis or tissues beneath; although this may remain a convenient term it would no longer be correct in every case to regard its function as that of water storage.) The condition of succulence has attracted the attention of morphologists in the past but only recently are we beginning to understand this problem. Various workers (Batalin, 1886; Lesage, 1890; Holtermann, 1907; Chermezon, 1910; Keller, 1925; Schratz, 1934) have all shown that there is a relation between the amount of sodium chloride present in the environment and the degree of succulence (total water content/superficial surface). Although it is possible that excess of sodium chloride is mainly correlated with the development of succulence in halophytes, it must not be forgotten that the phenomenon can be induced by other means and that in nearly every case a proportion is determined genetically. Succulence, for example, has been produced in *Tradescantia* by nitrogen starvation (Chapman, 1931), while Pearsall and Ewing (1929) have been able to bring it about by employing excess nitrogen. Succulence is also a prominent feature of certain desert plants, and here there is evidence to show that it is related, in those species investigated, to a peculiar form of metabolism, known as acid metabolism. This acid metabolism is not a common feature of halophytes although it is known to occur to some extent.

Experiments carried out by van Eijk (1939) have shown that the degree of succulence in *Salicornia herbacea* agg. is determined largely by the Cl^- ion independently, to some extent, of the other cations to which it is attached. It is true that as long ago as 1928 Stocker had expressed the view that the development of succulence was due to the action of specific ions rather than to changes of osmotic pressure, but no quantitative work appears to have been done until van Eijk's study. This is of such importance that it is perhaps worth while reproducing the data (Table 1).

If the operation of the different cations (upper half of table) is compared, it will be noted that the Cl^- ions have a distinct effect upon succulence in comparison with the NO_3^- and $SO_4^=$ ions. Sodium chloride, however, appears to operate in a special way, because a very high concentration e.g. $\frac{6}{1}$ mols., produces a large effect on the degree of succulence, although there is a considerable degree of variation: this phenomenon is also suggested in mixtures with potassium chloride, calcium chloride and sodium sulphate where there is a high proportion of sodium chloride. Apart from the Na^+ ion it seems that the Ca^+ ion also may have an effect uponsucculence, because it produces a considerable increase at $\frac{2}{1}$ mols. concentration, though here again the degree of variation is considerable. We may note too that the degree of succulence is raised by the NO_3^- anion when mixed with Cl^-, especially when the former is in excess, so long as sodium is the cation. The $SO_4^=$ anion, however, has a marked depressant effect either alone or in combination with Cl^- ions. The importance of

these results lies in the emphasis that has to be laid on the combined effect of the individual ions, and it is clear that future work on the halophytes must depend largely upon more detailed studies of the ions and their effects. This is a point that will be referred to later, but some surprise may be expressed that this important phenomenon in the halophytes has been more or less overlooked during the last twelve years. At present it is not clear exactly how the ions, either alone or in combination, achieve their specific effects; it is possible that they have some effect upon the biocolloids in the cell walls, and future work might well be turned in this direction. Another possibility is that the that there was no great change in succulence as the concentration of Cl^- ions increased. There is some evidence, however, that the leaves of mangroves are more succulent under certain conditions (Walter and Steiner, 1936; Holtermann, 1907).

Before leaving the problem of succulence we may refer again to the possibility that acid metabolism may in certain cases be concerned in promoting succulence in halophytes. At present far too few examples have been investigated for us to make dogmatic statements about the cause of succulence. Plants, in which a high concentration of certain ions is suspected of being the causal factor, when grown under conditions in which the ions are

TABLE 1

*Degree of succulence in Salicornia herbacea grown in different salt solutions**

CONC. IN MOLS./LITRE	NaCl	KCl	$CaCl_2$	$MgCl_2$	$NaNO_3$	Na_2SO_4
0/0	33 ± 1.0	33 ± 1.0	33 ± 1.0	33 ± 1.0	33 ± 1.0	33 ± 1.0
1/12	36 ± 1.5	39 ± 1.2	40 ± 1.0	41 ± 1.4	36 ± 1.8	36 ± 0.9
2/12	39 ± 2.1	29 ± 1.2	47 ± 3.0	42 ± 1.4	37 ± 1.7	—
4/12	45 ± 1.2	42 ± 1.0	—	45 ± 2.0	34 ± 1.2	36 ± 0.3
6/12	43 ± 1.1	43 ± 1.1	—	—	—	—
8/12	51 ± 4.0	42 ± 1.0	—	—	—	—

PROPORTION OF MIXTURES**		NaCl/KCl	NaCl/$CaCl_2$	NaCl/$MgCl_2$	NaCl/$NaNO_3$	NaCl/Na_2SO_4
4/12	3:1	52 ± 5.3	47 ± 1.3	44 ± 2.3	43 ± 2.0	46 ± 2.2
	1:1	47 ± 4.2	46 ± 1.7	—	—	—
	1:3	47 ± 2.8	42 ± 1.9	46 ± 1.5	48 ± 4.3	41 ± 1.7
8/12	3:1	46 ± 2.1	—	—	—	—
	1:1	44 ± 2.6	—	—	—	—

* There was also a basic culture solution from which these salts were otherwise absent.

** Basic value 33 ± 1.0 in pure culture solution.

development of mucilages in the plant cells may be correlated with the presence of the ionized salts. Van Eijk (1939) very pertinently points out that it must be the accumulation of the individual ions in the growing parts of the plant that has such a profound effect upon its structure. This, however, is not the whole story. Walter and Steiner (1936) have shown that there is a low percentage of sodium chloride in the seedling tissues of *Avicennia marina* and *Rhizophora mucronata* when on the tree, but that it increases rapidly very soon after the seedling has fallen to the ground. The present author working with seedlings of *Avicennia nitida*, *Laguncularia racemosa* and *Rhizophora mangle* found the same phenomenon, but a morphological examination of an age series of *Avicennia* seedlings indicated absent do not necessarily lose their succulent character. It would seem that there is a basic degree of succulence, which is determined genetically, and that an increase in the degree of succulence can be super-imposed upon the genetical quantity by other external or internal factors (e.g. ions or acid metabolism). The problem is rendered even more complex by the fact that such features of the environment as temperature may influence to an appreciable extent the interaction of the ions (Mevius, 1927). Future work should aim at 1) establishing the degree of succulence which is genetically controlled; 2) ascertaining the primary causes of any superimposed succulence, together with the effect of the environment; and 3) determining the effect of any environmental factors.

III. DIFFERENTIAL ABSORPTION OF IONS

For some years it has been known that certain plants, and indeed probably all plants, do not absorb any one electrolyte in its molecular proportions but that either the anion or the cation will be absorbed to a greater extent. Such a process, of course, involves maintainance of the charges within the cell by the loss or addition of an equivalent quantity of other ions of the opposite sign to the ion concerned. It is evident that the work on this aspect, together with the results of van Eijk on the effect of different ions, reopens and enlarges the vista surrounding the halophytes. Even more important, however, will be the concentrations of

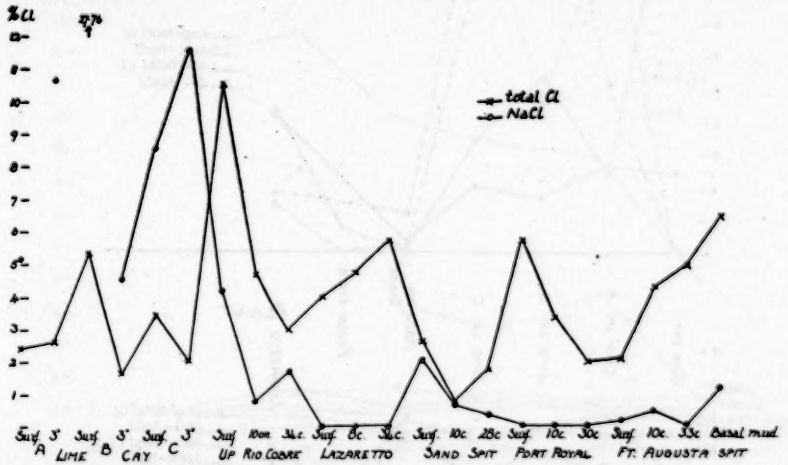

FIG. 1. TOTAL CHLORIDE AND CHLORIDE EQUIVALENT OF THE EXCHANGEABLE SODIUM IN SOME SOILS FROM JAMAICAN MANGROVE SWAMPS

the various ions within the plant tissues, because upon these will depend the nature and quantity of any more that may be absorbed. If we take our analysis yet further we ought to consider whether the ions are present in the sap or the cytoplasm of the individual cells. There is thus a whole chain of inter-relationships about which relatively little is known. The present author has shown (1939, 1940 and in prep.) that among the salt marshes of Norfolk and New England and in the mangrove swamps of Jamaica the amount of exchangeable sodium in the soil (estimated by a standard method of soil analysis) will not account by any means for the total quantity of chloride available, though in such soils we must suppose that the bulk of the chloride will be present originally as sodium chloride because of the great excess of this salt in sea water (Fig. 1). One feasible explanation that offers itself is that the sodium and chloride ions are held to different extents by the soil colloids and that the sodium ions are more tenaciously bound than the chloride (we have to assume that no greater quantity can be extracted by the plant than by the soil chemist). This may mean that there is a more ready supply of chloride ions for the plant than there is of sodium, so that theoretically there is the possibility that the plant may absorb rather more of the former than of the latter. This would result in a differential proportion of these ions in the plant tissues; as there seems to be a predisposition for chloride ions to be more readily available in the soil water than sodium so one might expect that the effect produced by the former would be more evident than that produced by the latter. The problem is not quite so simple. There is no evidence that the plants absorb the two ions in the same proportions that they are available in the soil: the current evidence all points to the contrary. Analyses of soils and portions of plants (whole tissues) of *Avicennia nitida* showed that though in both cases there was an excess of total Cl^- ions over the amount that theoretically should be present as sodium chloride (based on analyses of exchangeable sodium), nevertheless the excess was appreciably smaller in the case of the plant organs. This fact resulted in a complete lack of correlation

between the ion contents of the soil and corresponding plant tissues over a range of habitats, but the explanation of this phenomenon may well be that suggested above (Fig. 2). The reverse was found in the case of *Salicornia herbacea* because there was a greater excess in the plant tissues as opposed to the soil in which the plants grew (Fig. 3). We may note that *Salicornia* with the greater excess of Cl^- ions is a pronounced succulent, whereas *Avicennia* with a smaller excess is not; we must remember, however, that nothing is known about the other ions that may be present in the plant tissues. An investigation into the differential distribution of the sodium and chloride ions in plants of *Phragmites communis* from different habitats showed that the type of environment may influence the internal distribution of these ions. In Fig. 4 are depicted analyses (potassium permanganate method used in analysis of total Cl: uranyl zinc acetate method in obtaining amount of exchangeable sodium) of internodes, rhizomes and leaves of two plants each of *Phragmites* from a salt marsh, an old reclaimed salt marsh, from a fresh-water habitat and from an area where the reed was actively colonizing a salt marsh. The first point to be noticed is the variation in distribution in the various tissues, e.g. in all four habitats there is an excess of total Cl^- in the rhizome: in some habitats there is an excess of total Cl^- in the leaves and in others an excess of exchangeable Na^+, i.e. there is more than sufficient Na^+ ions to account for the total Cl^- ions present. In the leaves of the marsh *Phragmites* there is an increasing excess of exchangeable Na^+ ions up to the apex, whereas in the fresh-water plant there is no great variation but there is a slight excess of total Cl^- in all the leaves.

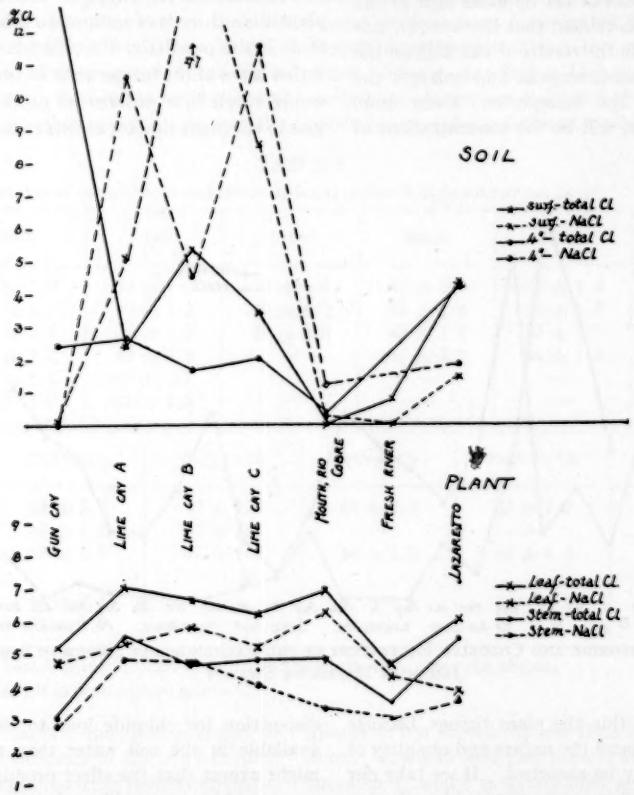

FIG. 2. RELATION OF TOTAL CHLORIDE AND CHLORIDE EQUIVALENT OF THE EXCHANGEABLE SODIUM IN PLANT TISSUES OF AVICENNIA NITIDA COMPARED WITH THE PROPORTIONS IN THE SOILS SURROUNDING THE PLANTS

The leaves of the colonizing *Phragmites* show a pronounced increase in the excess of total Cl^- towards the apex, while in the plants from reclaimed marsh there is an excess of exchangeable Na^+ at the base and of total Cl^- at the apex. The distribution of ions in the nodes, though not so spectacular, also shows considerable variation. In the marsh plants there is a slight excess, which does not vary greatly, of Na^+ in the upper nodes, while in the fresh-water plant there is a slight excess of total Cl^- throughout. The colonizing plant is again the most interesting with an excess of exchangeable Na^+ ions at the base leading to a reversal and an excess of total Cl^- at the apex.

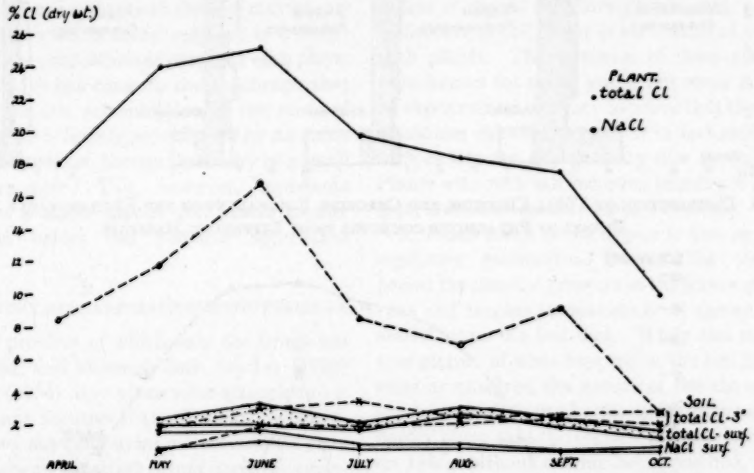

FIG. 3. RELATION OF TOTAL CHLORIDE AND CHLORIDE EQUIVALENT OF THE EXCHANGEABLE SODIUM IN PLANTS OF SALICORNIA HERBACEA COMPARED WITH THE PROPORTIONS IN THE SURROUNDING SOIL

This is not the place to consider how these results are related to the different environments, but they are important because they demonstrate the profound effect that the type of habitat may have upon the distribution of certain ions within plant tissues. Again this is an aspect about which we know remarkably little.

Before leaving this subject we may refer to seasonal changes in the distribution of the Na^+ and Cl^- ions in different tissues. In Fig. 5 the annual drift of these two ions during the first year's growth of comparable and even-aged plants of *Aster Tripolium* shows that the leaves have an excess of total Cl^- which gradually decreases towards the end of the year. The well-marked seasonal optimum in August is also worth noting. The roots commence by having a large excess of total Cl^-, but by the end of the year the position is reversed and there is an excess of exchangeable Na^+ ions; similarly the considerable excess of total Cl^- found in the rhizome of the seedling is reduced to a negligible quantity in the adult by November. Not only, therefore, does the environment have to be considered but also the season of the year and the plant tissue. In this particular case no data are available to show whether the ontogenetic drift is correlated with changes in the degree of succulence.

One is forced to the conclusion that much of our work on the halophytes and their behavior will have to be repeated in the light of these preliminary results. Apart from the little we know about the behavior of the Na^+ and Cl^- ions there is a considerable number of other ions which have scarcely been investigated in relation to their effect on morphology. So far we only know something about the effect of one or two individual ions on a few species, while we know much less about the distribution of these ions in the halophytic soils and hardly anything about their absorption by the plants. On the other hand it does seem that an attack along these lines should yield extremely valuable information and enable us to obtain a better grasp of the halophyte problem as a whole.

We may also briefly consider here the phenomenon of salt accumulation against a gradient and its effect on root respiration. In those plants where

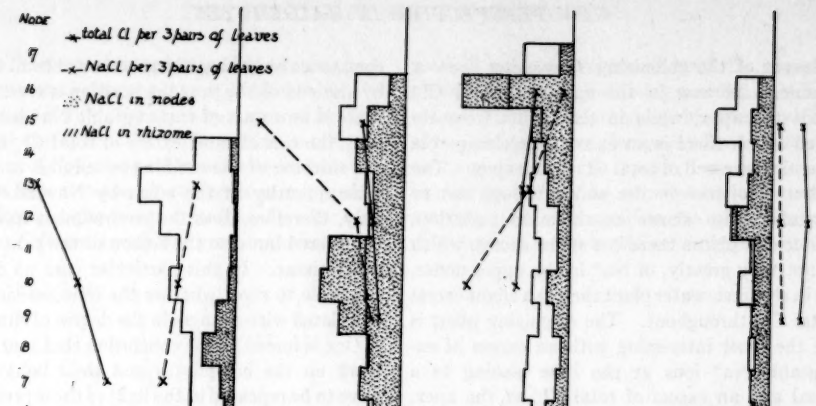

FIG. 4. DISTRIBUTION OF TOTAL CHLORIDE AND CHLORIDE EQUIVALENT OF THE EXCHANGEABLE SODIUM IN PLANTS OF PHRAGMITES COMMUNIS FROM DIFFERENT HABITATS

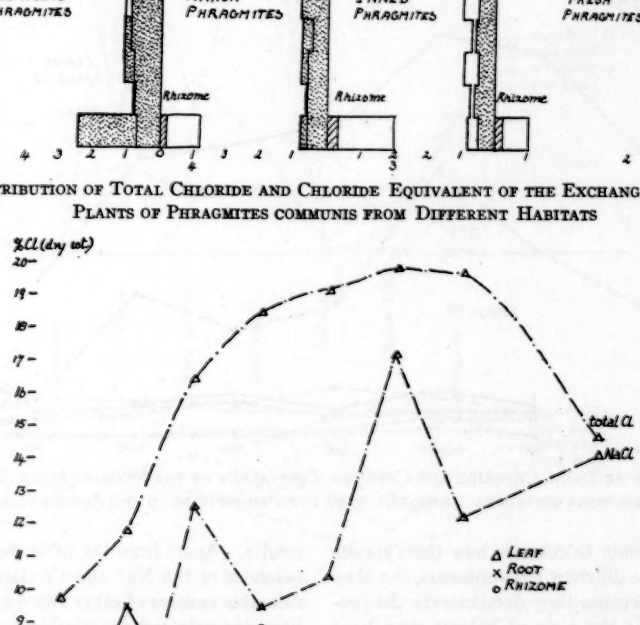

FIG. 5. ANNUAL DRIFT OF TOTAL CHLORIDE AND CHLORIDE EQUIVALENT OF THE EXCHANGEABLE SODIUM IN FIRST YEAR PLANTS OF ASTER TRIPOLIUM

there is an accumulation of one or more ions against a gradient work must be done if the process is to take place. We know that such an accumulation of sodium and chlorine does occur in halophytes so that we are forced to conclude that the necessary work must be done. At this point we have to consider two rival theories; those of Steward (1935) and Lündegårdh (1939). The former postulates that the extra energy for this work is provided for by an increase in the general level of respiration, while the latter argues that there is a special increase, which he terms the 'anion respiration.' At present the position is more or less fluid and further study of the halophytes should materially contribute towards a definite decision. It is not impossible, of course, that both theories may be correct, and that what is really required is a determination of the proportionate part that each plays. Van Eijk (1939) has come to the conclusion that the energy for salt accumulation in the roots of *Aster Tripolium* is largely provided for by an anion increase in respiration, though there may be a small cation component. This, however, represents results from a single species and others require investigation before this problem approaches solution.

IV. REGULATORY MECHANISMS OF OSMOTIC PRESSURE

This is a problem of which only the fringe has been touched, and although both Stocker (1928) and Steiner (1934) have given some attention to it there are many features that still await investigation. Among the halophytes, where osmotic pressure must depend to a large extent upon the excessive amount of sodium and chlorine present, three distinct groups have been recognized.

1. *Succulents.* In this group it is supposed that an increase in the sodium chloride uptake is compensated for by a corresponding dilution of the internal solution. There must, however, be a limit to the amount of water that the tissues can absorb and store, and one would suspect that during the growing season there will in fact be a steady small increase in the osmotic pressure. Unfortunately we do not possess the relevant data. According to Stocker plants of this type will only take so much sodium chloride out of the soil as they can use or tolerate. The regulatory mechanism, however, is not unlimited and after a time the organ ceases to function: in the case of *Salicornia* the water storage tissue dries up leaving only the woody stele. This implies some sort of regulation of absorption, but there is no quantitative data in support of this hypothesis other than the fact that increases of sodium chloride in the tissues do not proceed at a rate comparable to corresponding increases in the soil. Another possibility is that there may be a great increase in the sodium chloride content during the seedling stage with relatively little later on. This seems especially true of mangroves and reference will be made to it later. As examples of the succulent category we may quote *Salicornia* spp., *Aster Tripolium*, *Arthrocnemon* spp., *Plantago maritima*, *Spergularia marginata*.

2. *Salt excreting forms.* In this group an increase in sodium chloride accumulation is counteracted by a corresponding recretion of the salt by means of special recretory glands, and, according to Stocker (1928), there is no control of uptake in such plants. The existence of these glands has been known for many years, but there is little or no experimental evidence to prove that the amount of sodium chloride recreted is in fact sufficient to compensate for any increase due to absorption. Plants with such salt recreting glands are *Spartina* spp., *Distichlis spicata*, *Glaux maritima*.

3. *Plants which do not appear to have any special regulatory mechanism.* During the vegetative period the osmotic pressure in the leaves gradually rises and reaches its maximum at the end of the season when the leaf dies. While this may be a true picture of what happens in the leaf there still remains unsolved the nature of the changes that are taking place in the perennial rhizome. It is hardly likely that the osmotic pressure here can go on rising without a limit being reached, and one therefore suspects the existence of a regulatory mechanism.

V. THE SOIL ENVIRONMENT

In an earlier paper on this same problem the present author (1936) referred to some results obtained by Steiner (1934), in which it was claimed that the osmotic pressure of the soil water in certain New England marshes varied in such a manner that it could be correlated with the ecological distribution of the vegetation. The measurements, however, were obtained cryoscopically and hence must refer to all the solutes present. Recent work has shown that electrolytes are not available in the soil in their molecular proportions, presumably due to differential colloidal absorption, so that Steiner's results, though interesting, need amplification. Later, Penfound and Hathaway (1938), in a study

of the marshlands of S.E. Louisiana, came to the conclusion that the zones to be observed there were probably controlled by the sodium chloride content, but here again no distinction was made between the action of Na^+ and Cl^- ions.

Walter and Steiner (1936) working in the mangrove swamps of E. Africa have shown that there is a series of isohalines as one passes from the sea edge of a swamp to the bare salina behind. How far these gradations really control the zonation of the adult plants is another problem. The present author has investigated the same phenomenon in the mangrove swamps of Jamaica, and while there is some evidence of a series of isohalines as one travels up an estuary, nevertheless it seems that the adult plant zonation is determined very largely by what takes place during seedling establishment; here there is a whole complex of factors in which salinity probably does not play any major rôle. In the salt marsh, however, the problem is perhaps different: the vegetation is low-growing and often shallow-rooted so that the roots are more subject to changes that can take place in the surface layers of the soil. In the mangrove swamps the shade cast by the trees must reduce the fluctuations in soil salinity to a considerable extent.

Apart from the mangroves the present author has given some attention to the environment of the salt marshes in Norfolk, England, and at Lynn, near Boston, Mass. In both areas the total chloride content in the different soil layers of the various communities fell to a minimum in the spring when seed germination may be expected to commence. A similar fall has been recorded from a saline habitat in Thuringia, where the percentage of sodium chloride fell from 5.2 per cent in the autumn to 2.8 per cent in the spring. A very recent study (Purer, 1942) of salt marshes near San Diego, California, revealed a similar spring minimum. This fact is of extreme importance because experiment shows that the seeds of many species will not germinate under other than low concentrations of salt, and it is the salinity of the marshes at this time of the year which must play a large part in determining the composition of the adult community and the rate of colonization. Stocker (1928) has pointed out that in many apparently haline areas it is only the surface layers that are so salt and that low values are recorded in the layers beneath. In such places plants are only kept out because seeds cannot germinate when lying on the surface soil where the salt content is high. The percentage germination of four species from some American marshes after freezing is shown in Table 2.

Similar germination studies have been carried out by the present author using seeds of British salt marsh plants (Table 3). These were not subjected to freezing because English marshes do not become frozen for a month or more as they do in New England.

From these tables it can be seen that the only species with any tolerance (in respect of germination) of excess sodium chloride is *Salicornia herbacea*, though *S. mucronata* and *Spergularia marginata* from America exhibit only a slightly lesser

TABLE 2

Percentage germination of four species after freezing

	SALICORNIA MUCRONATA		SPERGULARIA MARGINATA		SUAEDA MARITIMA		PLANTAGO OLIGANTHOS	
Tap water.....	30	48	80	90	12	24	5	5
1 per cent NaCl...	28	50	100	95	6	10	0	0
2 per cent NaCl...	14	14	52	25	2	0	0	0
3 per cent NaCl...	2	8	32	0	0	0	0	0
Freezing temp.....	−10°C.	−20°C.	−10°C.	−20°C.	−10°C.	−20°C.	−10°C.	−20°C.

TABLE 3

Percentage germination after 28 days

	PHRAGMITES COMMUNIS	ASTER TRIPOLIUM	SPERGULARIA MARGINATA	SALICORNIA HERBACEA	SUAEDA MARITIMA	JUNCUS MARITIMUS	ARTEMISIA MARITIMA
Tap water.....	4	45	66	93	4	50	86
1 per cent NaCl...	32	25	4	45	0	18	8
2 per cent NaCl...	16	10	0	36	4	5	0
Sea water (3.3 per cent NaCl).....	0	0	0	38	0	0	0
5 per cent NaCl...	0	0	0	36	0	0	0
10 per cent NaCl..	0	0	0	12	0	0	0

degree of tolerance after being frozen. The prehistory of the parent plants, e.g. whether they grew in haline, brackish or fresh-water habitats, is of some importance, not only in determining the percentage germination but also the subsequent seedling growth rate (Fig. 6). In the submerged halophytes adventitious root formation is dependent upon variations in salinity in the surrounding medium, e.g. in *Zostera marina* it will only take place over a narrow range, 1.5–3.0 per cent, while in *Ruppia rostellata* it takes place over a wide range, 0–8 per cent, so that here also different species exhibit different degrees of tolerance. The control exerted by sodium chloride over germination is not the whole problem: not even the euhalophytes will grow in pure sodium chloride solutions, so that balanced media are necessary even for them.

Returning once more to the concentration of sodium chloride in the soil we can note that there may be very definite changes in the vertical gradient at one or more times during the year. These were very pronounced in a study of an American marsh (Fig. 7), and such changes may be of considerable significance in relation to the physiology of the roots. On the whole, however, the tolerance of many halophytes towards excess sodium chloride is much wider than may be expected (Penhallow, 1908; Penfound and Hathaway, 1938). In places where the vegetation is low-growing, rainfall during the summer months may have a profound effect upon the salinity of the surface layers of the soil, and this in turn may be of importance for the roots of small annuals, e.g. *Salicornia* spp. and also those of the grasses, e.g. *Puccinellia maritima*, *Distichlis spicata*, *Spartina patens*. A complex of factors is responsible for the salinity of the soil water at any given season, and hence it is very difficult to determine to what extent salinity itself plays a major part in controlling the zonation. In both Norfolk and New England there is remarkably little evidence of any great variation in the chloride concentration of the soil water as one proceeds from the lower to the higher marshes, because such gradients as one might expect are frequently masked by other factors, e.g. height of vegetation and control of evaporation. Fig. 8, showing variation in salinity during June-August from different communities on such marshes, is instructive, but all the evidence slowly but surely leads to the conclusion that the answer is not to be sought so much in a study of the environment of the adult plants but in a study of the seedling stages and the process of their establishment. The potent factor may be the concentration of sodium or chlorine in the soil water at this stage, but much of the work will have to be repeated because we must know which ion is concerned. It is evident that detailed studies and analyses of plants during the young stages are the primary requirements.

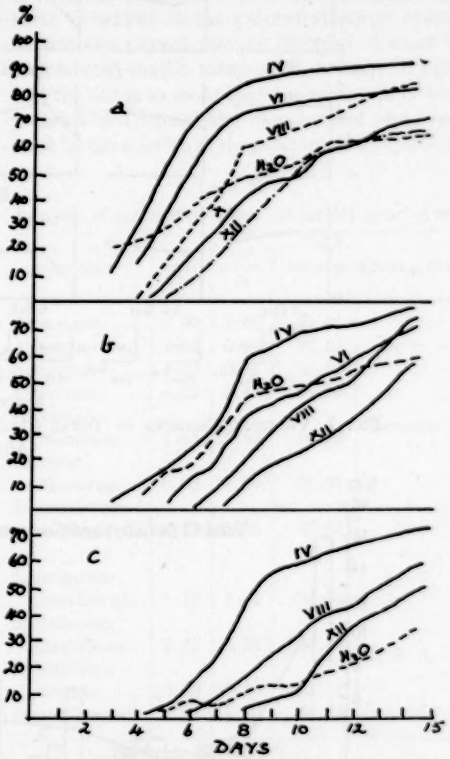

FIG. 6. EFFECT OF DIFFERENT CONCENTRATIONS OF SALT UPON GERMINATION OF SEEDS OF ASTER TRIPOLIUM

(a) Seeds from plant in fresh water habitat. (b) Large seeds from plant in saline habitat. (c) Small seeds from plants in saline habitat. The figures on the curves indicate the osmotic pressure of the solution in atmospheres. (After Schratz.)

Apart from sodium chloride, however, there are other soil factors that merit consideration. The movements of the water table may be of profound importance in determining the distribution of certain species. Evidence has accumulated to show that drainage conditions determine whether seedlings of *Obione portulacoides* can grow in a particu-

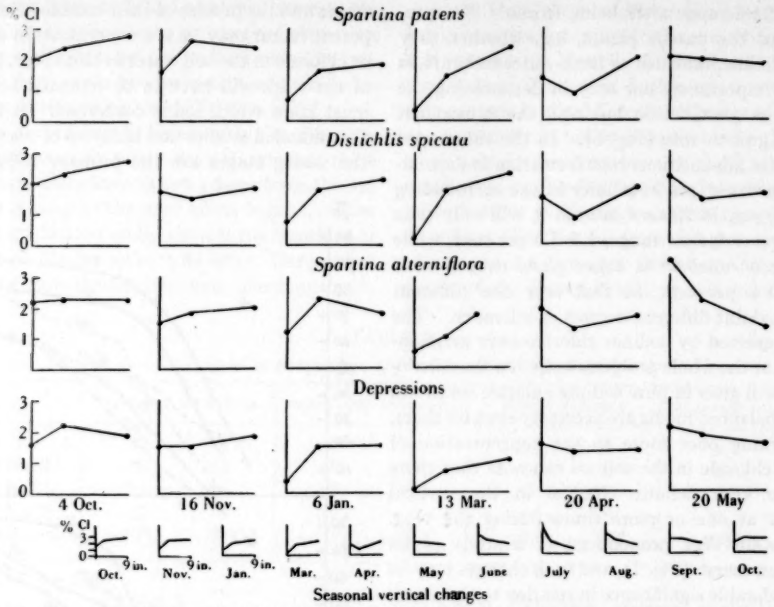

FIG. 7. VERTICAL CHANGES IN TOTAL CHLORIDE IN SOME AMERICAN SALT MARSH COMMUNITIES (After Chapman.)

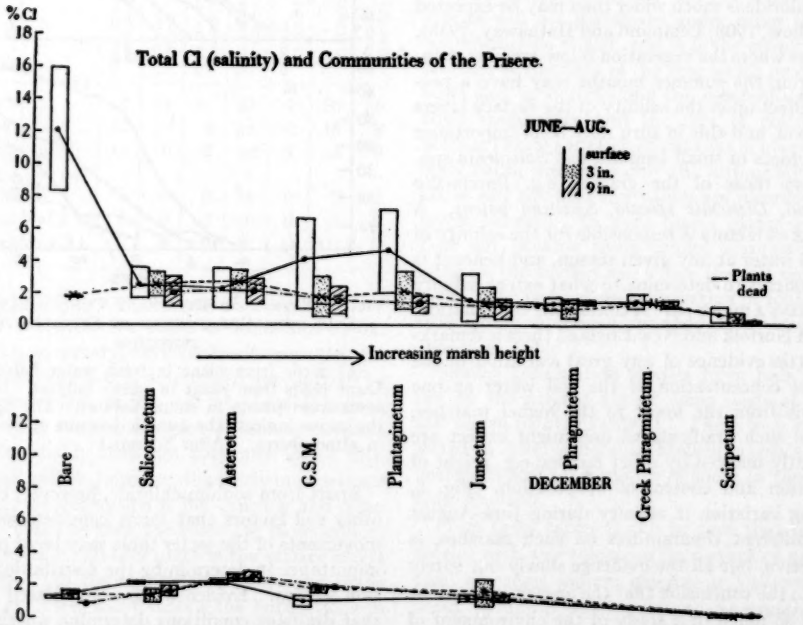

FIG. 8. TOTAL CHLORIDE IN RELATION TO THE SERAL COMMUNITIES ON NORFOLK SALT MARSHES (After Chapman.)

lar area or not. Seedlings which are water-logged experimentally commonly die after a short period even when the operation is carried out *in situ*. The adult plant may sometimes succumb to this treatment, though once plants of this species have passed the seedling stages they become much more resistant. This again brings us back to the great importance of the seedling stage, a phase which perhaps does not at present receive the attention from ecologists which it deserves. The response of the seedling to drainage is the principal reason that *Obione portulacoides* is commonly to be found fringing the banks of creeks on salt marshes, where it has been shown (Chapman, 1938) that the drainage conditions are good: on Holme marsh in Norfolk certain creeks have become dammed and converted into pans by a shingle fan thrown over the marsh by the waves. In these pans, where water now stands for much of the year, many of the adult *Obione* plants have died, and the effect is striking when compared with the unaffected creeks nearby. Another species which also appears to be influenced in its distribution by drainage is *Suaeda fruticosa*, whilst the occurrence of both *Aster Tripolium* and *A. subulatus* is primarily determined by the concentration of sodium chloride in the surface soil at the seedling stage. We need to know far more about the biological responses of the individual species. Future work on the eu- and miohalophytes should be directed to this end rather than to the continued study of communities as such.

We must also re-orientate our outlook upon the subterranean environment of plants growing in salt marshes and mangrove swamps. In the past it has commonly been thought that when the tide floods a marsh all the roots will be waterlogged. Work, both in Norfolk and America, has disproved this, and has shown that over the bulk of the marshes when there is a flooding tide an aerated layer persists just beneath the surface of the soil. This layer varies in depth depending upon a number of different factors, e. g. type of soil (sand or clay), heights of previous tides, distance from creek, etc., but it is important to note that a very large proportion of the total quantity of absorbing roots belonging to the different species will be present in the aerated layer. The occluded gas can be extracted and analyzed, and although much of it may be hydrogen sulphide nevertheless there are measurable proportions of both carbon dioxide and oxygen as the following table (Table 4) will show.

The most striking features are the relatively low values of oxygen, some of which are so low that respiration of the roots may be seriously affected, and the relatively high proportion of carbon dioxide. If the soil atmosphere is in communication with the external atmosphere, as field observations suggest it must be, then diffusion and interchange of the gases cannot take place readily. Although great variations in the concentrations of carbon dioxide and oxygen may be recorded, it must be remembered that in many of the halophytic habitats the soil is so moist that the roots will be surrounded by a definite film of water and first there must be the solution of the gases by this film before

TABLE 4

Analysis of gas extracted from the aerated layer of soil

COMMUNITY	PER CENT CO_2	PER CENT O_2	PER CENT RESIDUAL GAS	
Asteretum.....	2.99	1.61	95.4	
Asteretum.....	2.55	0.82	96.63	
Asteretum.....	3.26	0.71	96.03	
Asteretum.....	4.22	1.42	94.36	
Glycerio-Obionetum...	1.46	10.50	88.04	ENGLAND
Glycerio-Obionetum...	0.93	17.50	81.57	
Salicornietum on shingle....	0.88	18.30	80.82	
Spartinetum alterniflorae..	1.79	3.42	94.79	
Spartinetum alterniflorae..	3.23	8.28	88.49	U. S. A.
Spartinetum patentis.....	0.58	17.30	82.12	
Distichlidetum..	1.17	17.30	81.53	

diffusion into the roots commences. These figures lead one to suggest that an investigation into the respiratory behavior of the roots of salt marsh plants under conditions such as those above should yield valuable results. In the mangrove swamps of the West Indies one can also detect an underground atmosphere, primarily confined to crab burrows and the holes left by rotting roots. In *Avicennia* and *Rhizophora* only the ultimate absorbing roots are exposed to this atmosphere because the rest of the underground system is protected by a thick corky coat, but this may not be true of the roots in other species. The roots, whether protected or not, must exist in a soil atmosphere in which again the oxygen is frequently

very low and the carbon dioxide very high. Here also, as well as in the salt marshes, there is scope for further investigation. No data appear to be available about the soil atmosphere in xero-haline habitats.

Before passing on it may be as well to refer to the mechanical composition of the soil in relation to the vegetation. The present author (1941) has pointed out that the salt marshes of Great Britain can be divided into four groups, and it has been suggested from superficial observation that the differences in vegetation are largely determined by the proportions of sand, clay and silt. The same kind of phenomenon can probably also be observed in the U. S. A., though perhaps to a lesser extent. In any case a study of the vegetation and soils of the Bay of Fundy, New England and coastal plain marshes might prove unexpectedly productive. This is a problem, however, of which only the fringe has been touched, largely perhaps because of the magnitude of its size and the vast areas that would require to be covered. A major survey of marshes on this scale ought to be made, and from present indications it is clear that significant results would be forthcoming.

VI. TRANSPIRATION

Much work has been carried out on the transpiration of halophytes but the results are conflicting because some workers report that they transpire at a faster rate than mesophytes and others that they transpire at a slower. There appears, however, to be no real distinction in transpiration rate between hygrohaline and xerohaline plants. There are at least two papers which indicate lines along which research might profitably extend in the future. In the one, Schratz (1935), using a very sensitive torsion balance and weighing 30 secs. after cutting and again 60 secs. later, found that miohalophytes transpire less than mesophytes, but he goes on to point out that the result obtained depends on the unit of measurement used, e.g. whether it is based on fresh weight or leaf area. In the genus *Plantago*, the three species *P. maritima*, *P. coronopus* and *P. major* form a series occupying habitats ranging from the halophytic to the purely glycophytic. Measured on the basis of fresh weight *P. major*, the glycophyte, showed the highest transpiration rate and *P. maritima* the lowest, while using leaf area the exact reverse was obtained. In order to overcome this anomaly Schratz suggested that a new unit of measurement should be employed, which he called the "*wasserumsatz*," that is, the time taken to transpire once the total weight of water contained by the plant. When a glycophyte and a succulent plant are exposed to desiccation for any length of time the transpiration of the former will drop rapidly, whereas that of the latter will tend to be maintained. The occurrence of plants in specific environments is more likely to be correlated to their *wasserumsatz* than to their transpiration rate as measured at a given moment. For the purpose in hand, therefore, the *wasserumsatz* would seem to be the best unit so far devised. The present writer is not aware of any application of this new basis, and one of the desiderata of the future should be its utilization in comparing the behavior of eu- and miohalophytes in relation to glycophytes.

The other paper to which reference must be made is that by van Eijk (1939) in which he shows that for *Salicornia herbacea* agg.: 1) by increasing the concentration of sodium chloride or calcium chloride the transpiration rate is lowered; 2) in the presence of sodium sulphate a high transpiration rate is maintained. Some of the graphs illustrating these points are seen in Fig. 9, and one may conclude from them that the more Na^+ ions are present the greater the lowering of the transpiration rate. This effect might of course be due to the increasing concentration of the Cl^- ions, but it is worth noting that when potassium and sodium chlorides are mixed in the proportion 3:1 the transpiration rate is increased relative to a pure solution of sodium chloride of equivalent concentration. The SO_4^- anion seems to have the opposite effect and when present balances the depressant effect of the Na^+ ions. Although Stocker (1928) had suspected that the transpiration of halophytes was controlled to some extent by the action of specific ions, these are the first quantitative data to be secured. These results are very important because they show that the transpiration of all plants from haline habitats will have to be re-studied from this point of view. Not only may the individual ions exert a direct effect but even more important will be the effect of the interaction of all the ions present.

Rather less evidence is available about both assimilation and respiration. Sodium chloride has a marked depressant effect on both processes in glycophytes, and also causes considerable depression in *Honckenya peploides* (aero-halophyte), but much less in *Salicornia* (Neuwohner, 1938). In

the case of assimilation it has been suggested that it is associated with disorganization of the chloroplasts and cell membranes (Montfort, 1926, 1927), but further study is required in order to analyze the effects of the individual ions.

VII. SEEDLING STAGES

Montfort and Brandrup (1927), Schratz (1934) and van Eijk (1939) have all studied the effect of sodium chloride upon the germination and growth of seedlings of certain salt marsh plants. In the case of *Aster Tripolium* it was found that optimum conditions for seedling development lay between fresh water and 0.39 per cent sodium chloride, and this has also been confirmed by the present writer. *Aster subulatus* from the American east coast marshes is even less tolerant of sodium chloride.

Montfort and Brandrup and van Eijk have also studied seedling development in *Salicornia herbacea*, and they find that the optimum conditions for growth lie between a concentration of 2.0 and 2.5 per cent sodium chloride. In some species, however, the previous history of the parent plant (e.g. type of locality in which it grew) may have a considerable influence upon subsequent growth of the seedling. We may note also that with increasing concentration of sodium chloride there is an increase in the death rate among the seedlings, but this is to be expected. Apart from the effect on germination van Eijk was able to show that the Cl^- ions, together probably with certain other cations and anions, exerted a controlling influence upon the form and development of the plant. This influence could not be due to the increasing osmotic pressure of the medium because in a series of solutions of sodium sulphate the osmotic pressure rose from 5–16 ats. without bringing about any effect. Above a concentration of 2 per cent sodium chloride the Cl^- ion appears to be a limiting factor. Generally speaking Na^+ seems to be the most favorable cation for growth, though it may also be promoted at low concentrations by increases in either Mg^{++} or NO_3^- ions. In nature, however, many euhalophytes, and prob-

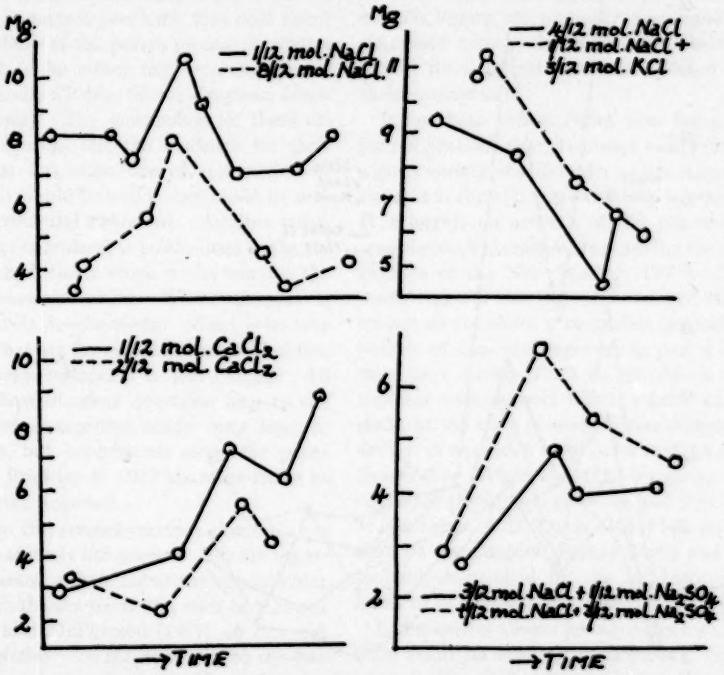

FIG. 9. THE EFFECT OF DIFFERENT CONCENTRATIONS OF SOLUTIONS OF VARIOUS SALTS UPON THE TRANSPIRATION RATE OF SALICORNIA HERBACEA (After Van Eijk.)

ably all miohalophytes, are to be found growing in areas where the percentage of sodium chloride in the soil water is more than optimal, although one must also consider interaction among the various ions. The occurrence of such plants under suboptimal conditions must be regarded as a result of competition with other species in those areas where the sodium chloride concentration is nearer their optimum. They do not grow in these places because the conditions are such that the other species are also able to flourish and dominate the vegetation.

There are still problems concerned with mangrove seedlings though these are to a large extent physiological rather than ecological. In 1936 Walter and Steiner discovered that the sodium chloride content of complete seedlings of *Rhizophora mucronata*, *Ceriops Candolleana* and *Avicennia marina* was much lower than that of the parent tissue surrounding them and also of ordinary sea water. In passing from the seed coat to the seed there was a transition from a region of high to one of low osmotic pressure, and it was suggested that the necessary negative absorption pressure occurred in the cotyledonary haustoria. A physiological investigation should be able to show to what extent this hypothesis is correct. Complete seedlings and portions of seedlings of *Rhizophora mangle*, *Laguncularia racemosa* and *Avicennia nitida* were analyzed by the present writer and the same phenomenon observed. In the last two species there was a sharp rise in the Cl^- content in the tissues as soon as the seedling had fallen to the ground (Fig. 10). It may be suggested that the rate of absorption of the sodium chloride is very high in proportion to the total dry weight of the

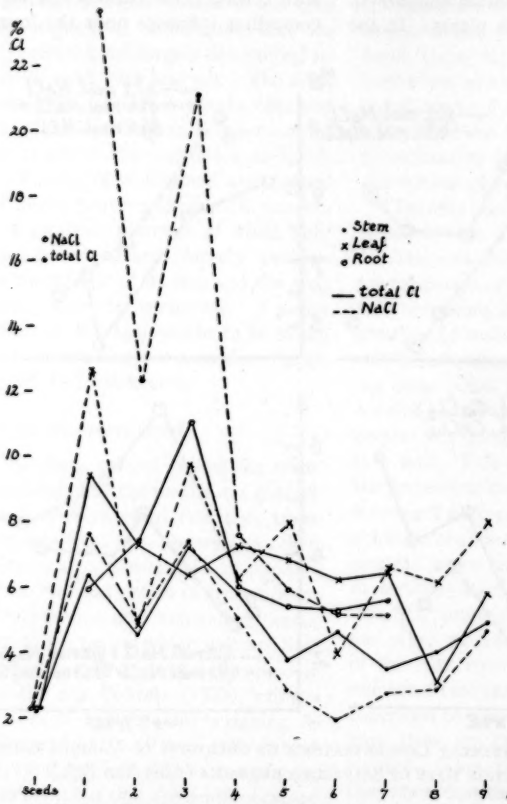

FIG. 10. CHANGES IN TOTAL CHLORIDE AND CHLORIDE ASSOCIATED WITH EXCHANGEABLE SODIUM IN A SERIES OF SEEDLINGS OF LAGUNCULARIA RACEMOSA

plant while it is still young, and that the rate subsequently falls off, or else that later a mechanism develops which controls the absorption of the Na^+ and Cl^- ions. Such a mechanism might well be concerned with the development of the characteristic periderm, but here again we are in the realm of hypotheses. The vista is there but it can only be trod with the aid of a study in physiological anatomy.

VIII. ANATOMY

One cannot do more here than refer briefly to some of the numerous problems that still await attention. Many of the genera possess structures that are said to be either salt recreting glands or else hydathodes (*Statice*, *Glaux*, *Spartina*, *Limonium*, *Avicennia*). The morphology of these organs is well known, but the evidence for their function is far too often one of supposition or analogy, and it would be well if they could be subjected to experimental treatment. Another structure that offers considerable possibilities is the so-called lenticel hydathode which can be found in the leaves of *Avicennia nitida*. What stimulus is responsible for its development? What is its true function? What are the causal factors behind this type of periderm formation in leaf tissues? All these and a host of other questions leap to the mind. Further anatomical study may lead to some advance, but experiments along the paths laid down by Priestley in 1922 are more likely to yield the correct answers.

There is also the aerenchymatous tissue that is such a feature of many halophytes. We are beginning to understand a little about the development of aerenchyma, thanks to studies such as those of Sifton (1940) and McPherson (1939) on *Zea* and *Thea groenlandicum*. So far, however, no one has investigated experimentally the problem of aerenchyma in the halophytes. Is it associated with lack of calcium salts, inadequate oxygen supply or too high a percentage of water in the soil? Another problem is the development of cork in the pneumatophores of the mangrove genera *Brughiera*, *Sonneratia* and *Avicennia*. Here again more excellent material is available waiting to be used in an experimental investigation.

IX. AUTECOLOGY

Really adequate autecological studies of individual species are extremely rare; nevertheless no major advance in our knowledge of halophytic vegetation will come until we are in a position to understand the life history, anatomy and reactions of individual species. This point was stressed in an earlier review (1936) and the need is still present. In 1936 I attempted to put together what was then known about *Salicornia herbacea* agg., though this was hardly satisfactory in view of the systematic confusion of the species. Since that time some work has been carried out on *Aster Tripolium* and *A. subulatus*, while we also know something about the biology of *Obione portulacoides*. The two halophytic species about which most is known are probably *Sonneratia alba* and *Avicennia nitida*. In both cases their morphological development has been studied and also their environment.

It has been shown (work now being prepared for publication) that *Avicennia nitida* can grow in a great variety of soils under a wide range of conditions; it is therefore an extremely tolerant species. It is largely on account of this tolerance that it occupies such extensive areas among the mangrove swamps of the New World. The available evidence suggests that the vertical distribution of the species on the shore is controlled primarily by the periods of non-tidal exposure (a period of two or more days during which no tide floods the area), together with indirect effects related to such periods, at the time of seedling establishment. We are not in a position to be quite so dogmatic about *Sonneratia*. While non-tidal exposure may account for the local occurrence and vertical range of *Avicennia*, J. H. Davis (1940) has pointed out that its geographical spread north and south is probably controlled by the incidence of killing frosts or of temperatures below 25°F.

In the case of *Obione portulacoides* we know very little about its seedling development, except that water-logging is inimical and that therefore it is commonly restricted to areas where drainage is good, e.g. along the banks of salt marsh creeks or on sandy marshes. Two varieties of this species are to be found in Great Britain, and their distribution is probably correlated with certain soil conditions. It is also possible that the northern limit of this species in Great Britain is related to the average monthly isotherms.

Aster Tripolium exists in Great Britain in two forms, a rayless variety, var. *discoideus*, and the normal plant with purple rays. The distribution of the rayless form is very restricted compared to that of the rayed as it appears only in southern

England and at Varel in Germany. The northern limit of the variety may be limited by the average monthly isotherms, though it is possible that it is still slowly spreading northwards. It has already been mentioned that the local occurrence of *Aster Tripolium* is controlled by the salinity of the soil surface in the spring when seed germination takes place. Once this species is established in a new area, however, further colonization takes place by disintegration of the clusters, the original rhizome commonly dying after two to three years. As the adult plant does not appear to be so sensitive to high salt concentrations it is able to invade areas other than that in which it started through vegetative propagation, and its spread to lower marshes by this means is probably controlled by the amount of submergence to which the plants are exposed rather than salinity. *Aster* also responds very remarkably to grazing as may be seen from plants on grazed marshes.

One cannot work on salt marshes without appreciating one fact of major importance, namely, that certain conditions may be necessary for the establishment of the individual species, but once they have arrived in an area further spread takes place steadily by vegetative means, e.g. *Puccinellia maritima*, *Aster*, *Spartina*, *Triglochin*. In any autecological study we have to consider two groups of factors which can control spread: a) those controlling the appearance of the species and b) those determining its subsequent spread. Generally these may be expected to show some difference.

X. GENETICS AND DISTRIBUTION

Some halophytes would seem to form extremely valuable material for genetical studies in relation to environment and geographical distribution. A paper by Gregor (1939) on the maritime sea plantains and their related alpine forms emphasizes this point. Gregor has been able to show that the North American, Greenland and North European maritime species are all diploid and that they can be regarded as forming, together with the diploid alpine species, one inter-fertile group or ecospecies (by an ecospecies Gregor means a population with an inherently low capacity for exchanging genes with other populations of its coenospecies). This group stands in contrast to the tetraploid alpine species which form another inter-fertile group or ecospecies. In the diploid maritime species only one abrupt transition is found, namely, the North American and Greenland forms are self compatible and typically have four seed capsules whereas the European plants are incompatible and have two seed capsules. In their other characters the so-called species overlap, although they frequently show a gradient related to (a) type of habitat in any region; (b) the transition from one geographical area to another (Fig. 11). The ecospecies may also be subdivided according to certain characters that occur locally. Iversen (1936) has pointed out that in ecospecies *Plantago maritima* on Danish marshes there are at least two varieties, vars. *subglabra* and *pilosa*. The former has a glabrous scape and grows on moist marsh soil and flowers during June and July, while the latter, which has a hairy

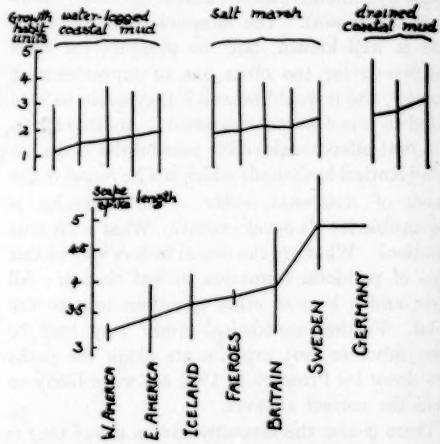

FIG. 11. GRADATION IN CERTAIN CHARACTERS AMONG THE MARITIME SEA PLANTAINS FROM DIFFERENT REGIONS OR TYPES OF HABITAT (After Gregor.)

scape, occurs on dry sandy soil and blooms from July to October. Iversen also noted that var. *subglabra* could be segregated into two forms: there was the normal plant which bloomed in July and there was also an early blooming *F. praecox* that flowered in June, and which, because of its premature flowering period, was not able to hybridize with var. *pilosa*. *Forma praecox* was also interesting because it grew in areas where marsh hay grass was cut, and it is possible that annual mowing has gradually selected out this early blooming form. Since marsh grass is cut in other parts of the world it would be of interest to ascertain whether there are other species which have responded similarly. *Armeria maritima*, for example, is a species which

might amply repay study in this respect since it is highly polymorphic and occurs on mountains and in salt marsh and other maritime habitats. Four varieties or races have already been distinguished; var. *maritima*, which has slightly fleshy leaves, var. *intermedia*, var. *elongata*, which is the alpine form, and var. *salina* from the Baltic. In Germany, Holland and Scandinavia segregation of these forms has taken place and each appears to possess a definite ecological significance. It would be well worth while studying this species in other countries where it occurs, employing for the purpose an extensive series of transplant experiments. Once again only the fringe of the problem has been investigated and an enormous field awaits the future investigator.

these two groups live under very different conditions, many of the species being restricted to either one or the other type. The segregation in the American marshes is not so obvious but more data would be desirable. Among the numerous subsidiary factors, which are related to the tidal movements, are the actual number of submergences per month, the hours submerged in daylight and the maximum periods of non-tidal exposure, this last item being of great importance depending on the time of year when it occurs. It is probable that each individual species living on a marsh is controlled to some extent by one or more of these factors, but until an attempt has been made to investigate their effects along experimental lines we shall not make much progress. So far, perhaps

TABLE 5

Analysis of tidal phenomena in swamp near Kingston, Jamaica

VEGETATION	LEVEL (ARBITRARY DATUM)	NUMBER OF SUBMERGENCES PER ANNUM	MONTH OF GREATEST SUBMERGENCE	MAXIMUM PERIOD OF NON-TIDAL EXPOSURE (*Days*)	SEASON OF MAXIMUM PERIOD OF NON-TIDAL EXPOSURE
Laguncularia/Conocarpus boundary	1.57′	4	October	339	November–September
Centre of salina	1.21′	150	October	125	December–March
Avicennia/Laguncularia boundary	1.14′	213	October	110	Mid-December–March
Avicennia swamp	0.84′	432	September	52	January–February
Avicennia/Rhizophora boundary	0.60′	524	August	10	January
Rhizophora swamp	Below 0.60′	530–700+	—	0–10	—

XI. TIDAL PHENOMENA

Although this is perhaps one of the major factors which operates where halophytic vegetation is to be found, it has deliberately been left to the end of this review because on the whole less is known about it than any other factor, and also it is so involved with subsidiary factors that it is well-nigh impossible to distinguish their effects. An analysis of the tidal factor has only been carried out for two sets of marshes in America (Johnson and York, 1915; Chapman, 1940), for one series in England (Chapman, 1938) and for some mangrove swamps in Jamaica (Chapman, in prep.). These analyses, however, have been sufficient to indicate some very important features, and it is highly desirable that this type of work should be extended to other areas. In England the salt marshes of Norfolk can be separated into two well-marked categories, the upper and the lower marshes, and the plants on

because of the magnitude of the problem and its complexity, no such attempt has been made. The problem in the mangrove swamps is of a slightly different nature because here submergence does not apply to the whole plant but only affects the roots and pneumatophores. One is apt to believe that most mangrove swamps are regularly inundated by the tide, but an actual analysis of the conditions produces results that are somewhat astonishing. Table 5 records the principal results of an analysis of the tidal phenomena in a swamp near Kingston, Jamaica.

Although the maximum tidal range is about one foot, a small rise or fall in level brings about profound changes in the number of submergences and in the maximum period of non-tidal exposure. The latter is particularly important, and it would seem evident that in the past insufficient attention has been paid to this factor, especially in its effect

on seedlings during the critical period of their establishment.

Apart from the effects of the tide upon the growth of the plants during their life there is also a mechanical effect which up to the present has only seriously been investigated for one species. Wiehe (1935) has shown that on the salt marshes of the Dovey, where the soil is sandy, the incidence of high tides during the first three days after germination may uproot a very high proportion of the *Salicornia* seedlings and hence seriously modify the annual distribution of the adult plants. Such an effect, of course, will only tend to operate in loose soils, i.e. soils with plenty of sand or shingle present or else composed of soft ooze. This mechanical effect is a feature that should be studied in mangrove swamps in relation to the distribution of the seeds and viviparous seedlings. The present author believes that it may have a significant effect upon the rate of colonization of an area by either *Avicennia nitida* or *Laguncularia racemosa*.

XII. CONCLUSIONS

The main purpose of this essay has been to summarize the more important recent contributions about the halophytes with the object of indicating the lines along which future development might be expected to be most profitable. The term 'halophyte' may be used in a general sense to include all plants which can tolerate more than 0.5 per cent sodium chloride, but those plants which are restricted to habitats where there is more than 0.5 per cent sodium chloride or whose optimal development takes place under such conditions should be termed 'euhalophytes.' The term 'miohalophyte' should be applied to those plants which are often found in haline habitats but whose optimal growth takes place under conditions where there is less than 0.5 per cent sodium chloride. Any plant which normally grows under glycophytic conditions but which nevertheless has some resistance to excess salt can be called a 'halo-glycophyte.'

The recent advances have been considerable and they demand radical changes in our future approach to the problems. In particular the effect of individual anions and cations on succulence, growth and transpiration mean that much of the past work will have to be repeated in the light of this new knowledge. There is also the differential adsorption of the ions in the various types of haline soils, about which remarkably little is known, while an associated phenomenon is the differential absorption of ions by the roots of the plants. Here too an almost virgin field awaits the investigator. Much still remains to be solved concerning the regulatory mechanisms of osmotic pressures in the halophytes, especially in those species where there is apparently no controlling mechanism. One of the more urgent problems demanding attention is a study of the factors controlling establishment and development of the seedlings of halophytes, together with the biochemical changes that take place in the developing tissues in relation to the accumulation of salts. This is not only of importance on general ecological grounds but it is essential in any autecological study.

The relation of the halophytic vegetation to soil types and soil characters, both physical and chemical, is a subject upon which we are woefully ignorant; such indications as there are suggest that a detailed study of this feature would add very considerably, not only to our understanding of the local distribution of the different communities, but also to a more general appreciation of the different seres that are to be found around the coasts. There is still a serious gap due to a lack of adequate autecological studies, and it seems clearer than ever that there is little hope of any great advance until we study each individual species in detail. In the past the halophytic vegetation and the seral successions have often been regarded as forming a relatively simple problem because of the great influence ascribed to sodium chloride. We are slowly beginning to realize the falsity of this position, and that we are really dealing with a bewildering complex of factors which results in successions that are as complex as any in ecological literature.

One of the environmental factors that would certainly repay more detailed investigation is that of non-tidal exposure, and its effect upon the individual plants at different stages of their life history. There are still anatomical features that have been given causal explanations in the past without any experimental proof, and such a position cannot be tolerated today. The euhalophytes and miohalophytes form excellent material for the application of experimental methods towards the elucidation of the functions of distinct anatomical structures, together with the interaction of the factors that are responsible for their development.

Much of what has been said applies more particularly to those halophytes which grow in the sea or on or near the shore. There is still a considerable population which inhabits inland haline seas and deserts. Conditions here are very different

from those on the sea-shore, and such plants and communities will require independent study. At present there are numerous descriptions of such halophytic communities and their component species but hardly anything is known quantitatively about their environment.

I am much indebted to Mr. G. E. Briggs, F.R.S., for his stimulating advice and criticism.

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THE DETERMINATION OF THE CASTES OF SOCIAL INSECTS

By S. F. LIGHT

Department of Zoology, University of California, Berkeley

POLYMORPHISM in the social insects and the history of the search for its causes received masterly treatment by Wheeler in his book, *The Social Insects* (1928). Since then there have been several attempts at experimental solutions of the problems of caste determination. The data thus far obtained are meagre, however, and statistical in nature, and it is obvious that data derived from experiments on social insects under laboratory conditions are especially difficult to evaluate. Because the problems of caste determination are of general biological interest and far from being solved, there has been a tendency to present conclusions despite paucity of evidence, and some of these conclusions have passed into the literature, although later findings have not substantiated them. Nevertheless, considered apart from these conclusions, the evidence obtained during the period since 1928 has shown a consistent trend. Until recently Wheeler had remained neutral with regard to theories of caste determination. In 1937, however, he undertook the defense of a position which is not in line with the trend of recent evidence or opinion. The time seems ripe, therefore, for a survey of the subject.

The fifteen years since Wheeler's book have seen marked advances in appreciation of the nature of the problems involved in caste determination. It must be emphasized, however, that in so far as the ants and the termites are concerned, only a beginning has been made toward the solution of these problems. Indeed, I feel it necessary to emphasize that the published researches of this period, as well as my own unpublished results, serve most importantly to emphasize the difficulties involved, especially as to laboratory methods and the analysis and interpretation of results. Further advances will depend largely upon the development of adequate methods of culture, rigorous scientific controls, and the application of suitable methods in evaluating the type of data resulting from such experiments. According to Goetsch (1936), the ideal approach is through the use of isolated individuals, and no doubt every effort should be made in this direction. But it is indeed a question whether the method is a feasible one with social animals. The individuals of an insect society are so highly interdependent (Emerson, 1939a, b) that the attempt to maintain and study them in isolation involves many of the difficulties encountered in isolating the organs or the cells of complex individuals, and, in addition, some which we call psychological, for lack of a more revealing physiological term. For example, C. S. Lafleur tells me (*in litt.*) that many ants when kept in isolation exhibit symptoms of extreme nervous agitation and, unless given company, die very shortly, as a result of nervous disturbance. To such obstacles to the study of social insects must be added those arising from cannibalism, endemic and epidemic bacterial diseases, and attacks of mites and fungi. Finally, there are the difficulties encountered in attempting to control moisture for organisms extremely dependent upon such a control, but accustomed at the same time to relatively great diurnal and annual shifts in temperature and helpless individually, or even in small groups, to effect such control. Control of factors and evaluation of their influence on experimental results must be accomplished by the student of caste determination, at least in the termites, when he seeks to use isolated groups, let alone isolated individuals, as controls and experimentals. If these problems are to be solved, they must be approached with full realization of the difficulties to be surmounted.

The general problem presented by the polymorphism of the social insects is, of course, the nature of the mechanisms which function in each generation of each species to cause the offspring of the same parents to develop, in relatively constant numbers, into several different types of individuals which possess the special morphological features and behavior patterns characteristic of the particular castes in the particular species, features correlated with the performance of special functions in the communal life.

There is plenty of evidence from the effects of parasitism to indicate that the ants are capable of responding very strikingly to purely somatic influences (Wheeler, 1928). Instances of the effects of parasitism on the development of individual termites are relatively few, but these few are striking. For example, certain peculiar individuals in Philippine colonies of the common mound-building termite of the Malayan region, *Macrotermes gilvus*, were described by Silvestri (1926) who showed them to owe their special characteristics to the effects on their development of a parasitic fly larva which develops in the head of the infested termite. I had encountered these individuals earlier and had designated them in my notes as "X caste" because of their structural differences and especially because of their distinctive behavior. They are larger than any other apterous individuals and attract attention by their rapid nervous movements. For all their differences it seems improbable that anyone would feel the need of postulating a special genetic mechanism to account for them. Yet these fly-infested individuals reach a terminal stage characterized by fairly definite size and distinct structural and psychological features. If they were present in all colonies, and in relatively stable numbers, they would almost certainly be considered a special caste, especially so if they performed some special function in the colony. As it is, they are to be considered as anomalous forms, and fall outside the field of our discussion except as they may serve to indicate the enormous range of differences between individuals of the social insects which may result from the influence of nongenic factors.

All modern students admit a genetic basis for the features of the different castes. The real problem is, therefore, whether the genetic factors determining the appearance of the different castes are segregated to certain individuals, which are thereby determined to become the particular caste, or whether, on the other hand, all individuals possess the complete genic complex, which would permit them to develop into any one of the castes (except in so far as sex determination is involved in the Hymenoptera).

It is obvious, of course, that the polymorphisms of orders so widely separated phylogenetically as are the Hymenoptera and the Isoptera (the termites) must be separate evolutionary achievements. Indeed, the arguments for separate origins of social habits in different groups of the Hymenoptera, the wasps, bees, and ants (Wheeler, 1928) are difficult to escape. Accepting the independent origin of polymorphism in wasps, bees, ants, and termites, it follows that findings with regard to one group have only the value of analogy when applied to the other. The argument from analogy does have its values, however (see Emerson, 1939a, p. 199), particularly when the proven facts with regard to some of the groups agree with the trend of the evidence in the others, as will be seen to be the case.

CASTES IN THE SOCIAL HYMENOPTERA

Social habits have originated several times among the wasps and bees and many species of each group are still solitary. The social habits of the ants are much more ancient than those of the wasps and bees and have undergone a multifarious evolution within the group (Wheeler, 1928, p. 173). Ants are all social and it must be supposed that they derive from a social ancestral stock.

Determination of the castes of the social Hymenoptera obviously includes two sharply distinct sets of problems. On the one hand are the problems arising out of the strong differences between the two reproductive castes, problems tied up, therefore, with sex determination. On the other hand are the very different problems which arise from the universal occurrence of distinct sterile castes, all individuals of which are female.

DETERMINATION OF THE REPRODUCTIVE CASTES

Strikingly different in structure, behavior, and rôle in the colony, the reproductively functional individuals of the two sexes of the social Hymenoptera have always been considered to constitute distinct castes. Here, as in most animals, the sexual dimorphism has a genetic basis. Further, it is typically associated here, as in other Hymenoptera, with major differences in the chromosomal complement, the males being haploid, the females typically diploid.

That male honeybees develop from unfertilized eggs, and females (queens and workers) from fertilized eggs, was first stated by Dzierzon (1845) and long defended by him, and has come to be known as Dzierzon's Law or Rule (see Wheeler, 1923, p. 139, and Whiting, 1935, p. 263). More recently there have been demonstrated structural mechanisms controlling the emission of spermatozoa from the spermatheca (see Snodgrass, 1925; Flanders, 1939).

Flanders (p. 13) says, "So far as we know at present, the control of fertilization in the honeybee depends upon the 'will' of the queen as asserted in 1845 by Dzierzon." Flanders concludes, however, that "the sex ratio of the eggs deposited by arrhenotokous species appears to be largely externally induced" and that in the case of the honeybee it is determined by the size of the available cells, drone cells being larger than other brood cells at the time the eggs are laid. In the parasitic Hymenoptera the sex ratio has been shown in several instances to depend upon external factors. For example, eggs laid by numerous parasites in hosts of optimum size are predominantly fertilized, whereas those laid in small hosts are predominantly unfertilized, and Flanders tells me (*in litt.*) that *Coccophagus ochraceus* "deposits diploid eggs in the body fluid of the black scale and haploid eggs out side of the body of the black scale." (For references and discussion see Flanders, 1939.)

The literature abounds in seeming exceptions to Dzierzon's Law. However, Goetsch and Käthner (1937), after summing up the evidence for the ants, state that without exception unfertilized eggs of worker ants and eggs of virgin queens give rise to males, and Whiting (1935) says that there is no evidence of males of wild species arising from fertilized eggs in the Hymenoptera thus far studied. True biparental males are reported to occur, however, in domestic and laboratory stocks (Whiting, 1935).

Some at least of the occurrences of seemingly uniparental females in the social Hymenoptera are known to be due to the fact that many egg-laying workers formerly assumed to be virgin are actually inseminated (Goetsch and Käthner, 1937).

Further indications of complexity in the genetic mechanisms concerned in sex determination in Hymenoptera derive from the common occurrence of sex intergrades and sex mosaics (Wheeler, 1928; Whiting, 1938). Bridges (1925, p. 134) pointed out that the mere doubling of chromosomes in the female could not account for female determination, and sex determination in the Hymenoptera is now explained on the basis of female heterozygosity and the action of a series of multiple sex alleles (Whiting, 1933, 1935, 1939, 1940; Bostian, 1939). Most of the work has been done by Whiting and his students, using the parasitic wasp *Habrobracon*, but it seems probable that similar conditions will be found to occur widely among the Hymenoptera. To explain the absence or very low incidence of biparental males, Whiting (1935) mentioned their low viability and tentatively suggested a theory of differential maturation to explain genetic results. The same year Snell suggested that femaleness results from heterozygosity with regard to one or more of a number of sex factors on different chromosomes, and pointed out that the chance of unrelated parents giving diploid males would be very slight if there were five independently segregating pairs of such sex determining genes.

Whiting (1939) proposed the theory of multiple alleles on the basis of the behavior of the gene *fused*. Introduced into two stocks having different sex factors, fused proved to be similarly linked with the sex gene, proving that these sex factors must be in a single series (at the same locus of the same chromosome). Bostian (1939) reported data indicating three members in a series of sex alleles thus showing Snell's hypothesis to be very improbable. Whiting (1940) reviewed the whole problem and later (1941) presented proof of a fourth member. He tells me (*in litt.*) that he now has proof of nine members of the series in his stock, and believes that others exist in wild strains. According to this theory (Whiting, 1940a, p. 333), "Any heterozygote is a female, any homozygote or azygote (haploid) a male." Biparental males are absent in crosses between unrelated strains (outcrosses) since the sex allele of the male is different from either sex allele of the female. In close-crosses of related strains their occurrence varies, but is usually low. The low incidence in close-crosses is explained by low viability, which is in turn affected by "diverse factors, both genetic and environmental" (Whiting, 1940, p. 354).

Whiting points out (*in litt.*) that the work of Speicher and of Inaba on other species of *Habrobracon* indicates that "the same principles probably apply to these forms" and that Dozorceva's work on *Pteromalus puparum* "shows that widely diverse branches of the order act similarly." In this connection it is interesting to note that Flanders, who has worked on the sex ratio of several parasitic species (1939, 1942a, b), says (*in litt.*) that he believes the diploid males obtained by Whiting are abnormal and probably due to sex reversal.

DETERMINATION OF THE DIFFERENT FEMALE CASTES

Determination of the two sexes and therefore of the two reproductive castes, as shown above, derives from genetic differences in the egg and is in accord, therefore, with the blastogenic theory (in

modern terminology, the genetic theory) of caste determination stemming from Weismann and upheld for the ants by Forel and, latterly (1937), by Wheeler. The differentiation of the two female castes presents, on the contrary, in the wasps and bees at least, an equally convincing case for control by extrinsic factors, in this case nutritional factors, in accord with the somatogenic, specifically the trophogenic, theory of caste determination as upheld by a long series of students, notably Wasmann and Emery.

The worker caste is poorly developed in most wasps. In ontogenetic development the first nonreproductive females (the only ones of many species) are sterile because of an adult starvation resulting from giving their food to the numerous larvae. Later in the same colony sterility results from alimentary castration, the larvae receiving minimal amounts of food and developing into small, sexually undeveloped worker adults (Wheeler, 1928, p. 167). Marchal (1896, 1897) found that elimination of the queen from a *Vespa* colony resulted in development of functional sexuality (egg-laying) by one-third of the brood, relieved under these conditions from nursing duties. He found that permanent or even temporary suppression of egg laying by the queen gave similar results.

"The differences between the workers and the queens of wasps are so small and intermediate forms are so numerous that quantitative feeding would probably account for their production. The normal sterility of the workers seems to be due to the acceleration of the somatic and retardation of the reproductive tissues, a condition the reverse of neotenia" (Wheeler, 1928, p. 196).

Caste development in the humblebees seems to be on the same basis as that of the wasps. In the stingless bees and the honeybee, however, the differences between queen and worker castes are exaggerated. The morphological specialization of the worker is more advanced, and the queens show numerous degenerative features. The queens of these societies, it must be remembered, are parasitic in a sense, entirely dependent on the workers and not functional in colony activities except as reproductives. The difference between queens and workers in the social bees then is by no means merely a matter of sex repression.

The method of determination of the distinct female castes is best known for the honeybee, although seemingly many points remain to be cleared up even here. The essential facts have long been known. Eggs laid in queen cells become queens, those in worker cells become workers. All young larvae receive the same food up until the middle of the third day. Queens receive the secretion of the pharyngeal gland known as royal jelly throughout larval life. The larvae in worker cells

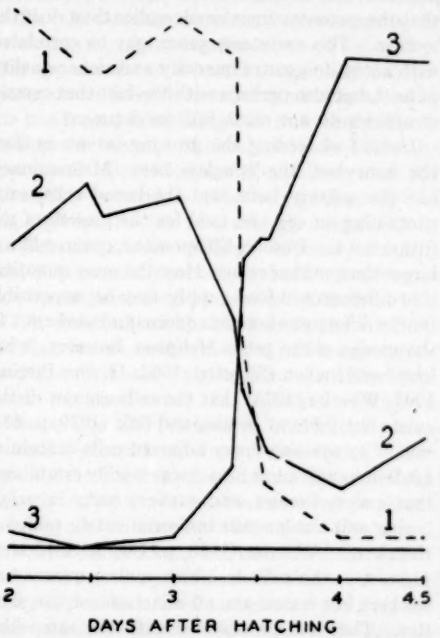


FIG. 1. SCHEMATIC REPRESENTATION OF SOME OF THE MAJOR CHANGES WHICH OCCUR IN THE DEVELOPMENT OF FEMALE LARVAE OF THE HONEYBEE IN WORKER CELLS DURING THE THIRD AND FOURTH DAYS OF DEVELOPMENT, FOLLOWING THE ADDITION OF POLLEN TO THE DIET. (FROM FIG. 24 OF BECKER, 1925)

1. Decrease in number of ovarian tubules. 2. Decrease in size of mandibular gland. 3. Increase in size of pharyngeal gland.

receive pollen in increasing amounts beginning from about the middle of the third day. Becker (1925, in Zander and Becker, p. 215) showed (Fig. 1) that sudden and striking change in direction and rate of development of the features in which workers differed from queens coincides with the first feeding with pollen. Up to this point any female larva seems capable of becoming either a queen or a worker, as has been shown by transfer-

ring eggs from worker cells to queen cells, and vice versa (Wheeler, 1923, p. 137). Furthermore, numerous intermediates have been produced by transferring worker larvae to queen cells at various times beyond the second and third days of larval life. Becker states that the queen and the worker are the extremes of a morphological series, the intermediates of which may be experimentally produced by varying the food. It should be noted that the queen emerges much earlier than does the worker. This early emergence may be correlated with access to greater quantity and richer quality of food, but also perhaps with the fact that certain structures do not reach full development.

Instead of feeding the growing larvae as does the honeybee, the stingless bees (Meliponinae), like the solitary bees, seal the brood cells, each containing an egg and food for the growth of the future larva. In some Meliponinae, queen cells are larger than worker cells. Here the mere quantitative differences in food supply may be responsible for the differences between queens and workers. In the species of the genus *Melipona*, however, it has long been known (Silvestri, 1902; H. von Ihering, 1903; Wheeler, 1928) that the cells are not distinguishably different in size, and Salt (1929, p. 435) says, "By opening many adjacent cells containing adult or nearly adult bees it was readily established that males, females, and workers occur in neighboring and similar cells indiscriminately mixed in the tiers." Wheeler (1928, p. 197) says of *Melipona*, "... the cells in which males, queens and workers are reared are all alike and of the same size. They are provisioned with the same kind of food, pollen and honey, and an egg is laid in each ... their uniform treatment nevertheless results in the production of two sharply differentiated female castes." If it should be shown that all brood cells contain the same food substances in the same proportions, we would have here inescapable proof of intrinsic differences in the eggs and, therefore, of the blastogenic theory. In the absence of evidence one can only predict in the light of conditions known to exist in the honeybee that further investigations will show that the food stored in cells in which queens develop is significantly different from that in cells in which workers develop.

DETERMINATIONS OF FEMALE CASTES IN ANTS

A consideration of female polymorphism in ants presents problems more complex and difficult and much farther from solution than is the case with the bees and wasps. The situation was admirably described by Wheeler (1937, p. 39) as follows.

> "It must be admitted that the brood relationship in ants is so elaborate, the difficulties of submitting it to controlled experimental investigation so great, and observations of it so conducive to conflicting 'explanations' that the controversy concerning the determination of castes in these insects has persisted with little change for many years. This is shown by the attitudes of the two very eminent myrmecologists, Emery and Forel. Although both were thoroughly conversant with all the relevant facts established during their lifetimes, Emery nevertheless remained an intransigent trophogenist throughout his career, and Forel ... was as thoroughly convinced that the castes are determined in the egg. During the past thirty years I have remained 'on the fence' on this controversy, with an increasing inclination to drop off on the blastogenic side."

In *Mosaics and Other Anomalies Among Ants* (1937), the last work before his death, Wheeler did definitely espouse the blastogenic theory (see quotation in preceding paragraph). He was led to this position by a study of the very numerous anomalies in a colony of the fungus-growing ant, *Acromyrmex octospinosus* Reich, collected in Trinidad by Dr. Albert Neal Weber, and studied by Weber there for three months in a laboratory observation colony. Wheeler believed these anomalies could only be explained as intercaste mosaics and therefore genetically determined as sex mosaics are known to be. Whiting (1938) in an extensive review of Wheeler's book showed that these and other ant anomalies could be interpreted as intercastes resulting from unusual and variable conditions as to nutrition or other environmental factors or as intersexes. Most importantly he points out that whereas the anomalous areas are distributed more or less at random in mosaics, the anomalies of ants tend to be limited to the head. Of the two other reviewers, one (Gregg, 1938) is also in disagreement with Wheeler's conclusions, and the other (Schmieder, 1938) feels that experimental evidence is still required to prove the blastogenic theory.

Two major sets of problems are involved in the female polymorphism of ants: first, those concerned with the determination of sterile versus fertile females, already discussed for bees and wasps, and, second, those dealing with the differentiation among the sterile individuals of distinct types known respectively as soldiers and workers.

First, then, the question already encountered in

the wasps and bees: Are the reproductive females on the one hand and the sterile castes on the other genetic segregants, or do they represent phenotypic extremes of a varying expression of the same genotype, their appearance determined by somatic influences? These are the two extremes of blastogenic versus somatogenic positions. A somewhat different somatogenic explanation would hold the existence of different genetic mechanisms for all female castes in all female-producing eggs, and postulate somatic (probably nutritional) factors which determine which of these genetic mechanisms shall function during the critical period of larval development.

In wasps, completely intergrading ontogenetic series exist between workers and queens, and in the honeybee such can be experimentally produced by variations in the diet. The presumption would be that such was once the case in ants. However, the polymorphism of ants is a much more ancient, much deeper-seated affair then in the other social Hymenoptera, and much more protean in its present-day expression. Individuals which are intermediate as to some characters between the queen and sterile workers occur naturally in some species, chiefly parasitic species, and such have been found to occur also when the natural development of individuals or the normal care of the brood is disturbed, as in various types and relations of parasitism. Whether the individuals thus caused to deviate from the normal of one or the other female castes actually form connecting series between queens on the one hand and a sterile caste on the other is a matter of opinion.

An extensive literature deals with the structural and psychological effects of infection of individual ants with nematodes of the genus *Mermis*. As late as 1928 Wheeler says (p. 206), "But whatever interpretation we adopt, the blending of characters of all three castes in the adult mermithergate seems clearly to point to potentialities for all of them in the young larvae." In 1937, influenced by the findings and arguments of Vandel (1930), and perhaps not entirely free from the influence of his own recent conversion to the blastogenic position, Wheeler says (1937, p. 77), "The character of the modification manifested by the adult ant depends therefore, on the caste of the infected larva," and he speaks of the trophogenic explanation of these anomalies given by him in 1928 as being "untenable."

The rich terminology of caste anomalies among the ants need not concern us here (see Wheeler, 1937, Appendix B, for his latest formulation, dictated by acceptance of the blastogenic position). Our consideration may be limited to those anomalous females known as pseudogynes, long studied by Wasmann and others. Their occurrence is definitely correlated in several ant genera with infestations of staphylinid beetles of several genera, chiefly *Lomechusa*, as shown by Wasmann in numerous papers, and by Viehmeyer (see Wheeler, 1928). The workers of infested colonies nurse the beetle larvae, neglecting the larvae of the colony. The appearance of anomalies, especially pseudogynes, under these circumstances was explained by the trophogenists as being due to irregularities in feeding the larvae. It should be noted that the appearance of pseudogynes persists long after the infestation has ended. This is explained by the trophogenists as due to continued irregularity in the behavior of the workers. It must be noted, also, that pseudogynes occur, also, in certain species "never parasitized by beetles" (Wheeler, 1937, p. 79), which allows the blastogenist to attribute their occurrence to irregularities in the eggs rather than to nutritional irregularities. In 1904 Viehmeyer obtained what he considers conclusive evidence (see also Viehmeyer, 1924) that these anomalies proceed not from irregularities in the eggs but from nutritional aberrations. A colony formerly infested with *Lomechusa* had produced pseudogynes for three successive years after cessation of the infestation. He transferred the queen of this colony to a group of workers from another colony which had never produced a pseudogyne. Under the care of these workers all of the eggs of this queen gave rise to normal individuals, none to pseudogynes. However, since we do not know all the causes of pseudogyne formation, Viehmeyer's results would have been much more conclusive had eggs produced by the transferred queen in the new colony been returned to the old colony as a control to demonstrate that they could still give rise to pseudogynes there. Even then the bearing on our question of these findings might be oblique, since pseudogynes are interpreted by Wheeler as abortive females (queens) and not as intermediates between the fertile and sterile female castes.

Various other types interpreted as intermediates between queens and workers are known to occur (Wheeler, 1928, p. 209; 1937, Appendix B). Some of these occur sporadically and are clearly abnormalities. Others, especially in the genus *Leptothorax*, are functional females, but "grading down from the winged queen to the smallest worker"

(Wheeler, 1928, p. 209). In 1937, however, he says (p. 62), speaking of *Leptothorax* again,

> Besides the sudden absence of the wings in the ergatogynes, there is also a perceptible gap in thoracic structure .... The series seems, in fact, to comprise two series, one of females, with loss of wings and increasing simpification of the thorax, the other of workers, which increase in size and acquire ocelli ... the semblance of a single graduated series seems to be produced by a recessive structural simplification of the females and a progressive increase in size and ovarial development (feminization) of the workers.

Ezhikov (1934), in an interesting statistical and theoretical discussion of individual variation and dimorphism of social insects, reports, without presentation of data, the general result of attempts to produce intermediates between workers and queens by quantitatively differential feeding: "When we subjected to hunger the larvae of ants destined to be females (*Camponotus*, *Myrmica*) at different moments of their development, we never were able to obtain forms transitional between the queen and the worker, but either real fertile females, perhaps somewhat reduced in size, or else typical working individuals."

Wesson (1940), approaching the same problem somewhat differently, attempted to show the effectiveness of environmental factors in shifting the proportions of queens produced from given numbers of female larvae. The young larvae from several colonies of *Leptothorax curvispinosus* were thoroughly mixed and introduced into a colony of *L. longispinosus* from which the queen and the brood had been removed. During two weeks at summer temperature, 32 per cent of the larvae disappeared and those persisting grew but little. Evidently there was incompatibility between brood and recipient workers. The mixed colony was then placed in the cold room at 2° C until March (five months later). On removal from the cold room another 33 per cent of smaller shriveled larvae was discarded and the remainder were thoroughly mixed again and the pile divided "into halves through the center." The host colony was divided into halves and each placed with one lot of the larvae. Colony A, consisting of 27 *longispinosus* workers and 44 *curvispinosus* larvae was given a superabundance of food. Colony B, consisting of 30 workers and 44 larvae, was given the same kind of food but just enough to allow the larvae to grow. Conditions otherwise were the same. The 38 larvae surviving to maturity in colony A gave rise to 3 males, 32 queens and 3 workers, whereas the 35 surviving in the starved colony gave rise to 2 males, 23 workers and only 10 queens. These results are interesting but are so meagre as to make it unwise to base generalizations upon them. As Wesson says, they could conceivably be explained upon the basis of chance assortment. Further, it would be extremely valuable in estimating the significance of these differences to have information as to the numbers of each caste developed from such larvae in colonies of the donor species under normal conditions and also after removal of queen and brood both during the summer and in the spring. Further, one would suspect that the adoption of the foreign brood could have been accomplished by brief refrigeration alone, and that the artificial hibernation was not the important factor. One wonders, also, as to the 65 per cent of larvae lost. Perhaps here, as in the case of laboratory groups of termites, wide differences which seem to be of experimental significance may rest rather in variations of unknown complex social and environmental factors whose results are expressed in great differences in viability. However that may be, this is an excellent beginning and it is from such experiments more elaborately controlled and involving larger numbers of individuals and colonies that valuable results may be expected.

Except for a few parasitic genera, in which, supposedly, it has been secondarily lost, all ants possess a sharply defined worker caste. In the primitive subfamilies of ants the workers are large and monomorphic (Wheeler, 1923), although sometimes of different sizes. In many species in each of the higher subfamilies the sterile females exhibit polymorphism which may take the form of a more or less completely intergrading series or may be a sharply defined dimorphism. In the latter instance the large sterile type is termed the soldier and the smaller type the worker. These two types appear regularly in each colony of such ants and have very different functions in the economy of the colony. They are, in other words, well-defined castes in the proper use of the term. Here, therefore, the question arises as to the mechanism which determines their occurrence. Two recent attempts at an experimental solution of this problem are of interest.

Goetsch reports, in the brief accounts available to me (1937a, b), what seem to be significant findings as to the effects of diet on soldier production in colonies of the Italian house ant (*Pheidole*

pallidula). This species is especially favorable for such studies because of the ease with which incipient colonies may be cultured and because of the rapidity of its colony development. The first nanitic worker lives only two to four weeks but by that time the second series of workers is present. These second workers are usually of normal size for workers of this species and in such colonies the first soldier is also present. Thus there is presented here somewhat the same opportunity for study of the factors concerned in soldier production in ants as is furnished for termites by the incipient colony of *Zootermopsis*, to be discussed later.

All of the 26 colonies which produced soldiers were colonies which (1) contained larvae not older than 5 days when experimental feeding was begun and which (2) were fed solid proteinaceous foods. Only one colony in this category failed to produce soldiers. None of those whose larvae were older than 5 days produced soldiers, and none was produced in 18 colonies with young larvae but fed syrup or solid sugar or even fluid protein. Six of 8 such colonies fed syrup together with solid protein food produced soldiers, and one fed syrup but given a single piece of animal food produced a soldier-worker intermediate. Goetsch (1937a, p. 15) concludes, evidently partly on data not quantitatively presented in the reference available to me, "Es ist also lediglich eine Spanne von höchstens 2 Tagen, in der über das Schicksal der Larven bestimmt wird. Bekamen sie während dieser Zeit Fliegen- oder Mehlwurmstückchen, dann wuchsen sie zu Riesenlarven und später zu grossköpfigen Soldaten heran; im anderen Falle blieben sie Arbeiter!" Such of his results as are presented in the brief report available to me are recombined in Table 1. As presented, they seem to indicate the significance of diet in determining the soldier caste. The argument is more compelling when one notes that the six colonies which did produce soldiers (and for which information is given for numbers of soldiers) produced 21 of them, which would seem to make truly significant their total absence in the 16 similar colonies otherwise fed. Striking as these results seem at first glance, more careful consideration raises numerous questions. First, it will be noted that the factor involved is not entirely clear. It is not just the chemical nature of the food, apparently, since, although colonies fed solid protein produced soldiers, those fed liquid protein (blood, expressed tissue juices, raw egg white) or those starved (but supposedly fed proteinaceous food) did not. This, Goetsch thinks, may be because the fluid materials had to be taken into the crop of the worker and fed to the larvae, whereas the solid protein food can be fed on continuously by the larvae; in other words, that it is a matter of quantity in the case of liquid proteins at least, as presumably also in the case of starvation. It should be remembered in evaluating these results that pieces of insect bodies are the normal food of the larvae of the species. From this point of view the findings seem less significant: Colonies with plenty of their normal food produced soldiers as well as workers whereas those receiving small quantities of the normal food, or the normal type of food but in a different (less available) form, or other types of food, produced only workers. As Gregg (1942) says, the better-fed colony would be expected to produce soldiers. Soldiers always appear later than workers in the development of ant colonies and are larger, and their appearance would seem to depend upon abundant food supplies. The factor actually determining that one larva shall become a soldier, another a worker, remains obscure, however. Finally, data as to the complete brood of these colonies as also as to mortality in the colonies which did not produce soldiers would have been of interest in evaluating these results. These data may be given in other articles not seen by me.

TABLE 1

Summary of results of experiments by Goetsch (1937) on the influence of food on soldier development in colonies of Pheidole pallidula

FOOD	AGE	NUMBER OF COLONIES	NUMBER PRODUCING SOLDIERS
Flesh	Young*	22	22
Flesh	Old	3	0
Solid protein	Young	5	4
Flesh and syrup	Young	8	6
Syrup and one piece of flesh	Young	1	1**
Fluid protein	Young	4	0
Fluid protein	Old	1	0
Tissue juice	Young	2	0
Syrup	Young	5	0
Solid sugar	Young	7	0
Solid sugar	Old	2	0
Starved	Young	8	0

* All larvae designated as young were less than 5 days old.

** Intermediate between worker and soldier.

In the same paper (1937), Goetsch reports on the nanism of the first worker. This he shows to be due to conditions in the egg, since eggs of young queens transferred to old colonies still give rise to nanitic workers. He considers nanism as an example of blastogenic determination, although he clearly considers it a matter of quantity of food available during embryonic development. Certainly there is no reason to think that these eggs are genetically different from the others. The time would seem to have come to discard the term blastogenic, unless it can be used in conformity with modern genetic usages. Its use otherwise can only lead to misunderstanding.

Most recently Gregg (1942) presents the results of a most interesting attempt to determine the significance of the constitution of the colony in determining the proportion of soldiers or workers produced within a colony. *Pheidole morrisi* was chosen because it is dimorphic as to sterile castes and because its soldiers are able to care for the brood. Numerous experimental colonies of varying sizes were set up. Seventeen were composed, aside from the queen, nearly or entirely of workers, 10 nearly or entirely of soldiers, and 6, as controls, of workers and soldiers as taken in the field. In the 6 control colonies, soldiers produced ranged from 0 to 17.5 per cent of the brood with an average of 7.3 per cent. In the 17 worker colonies, caste production was not strikingly different from that in the controls. Soldier production ranged from 0 to 18.6 per cent of the brood in 16 colonies and was 46.5 per cent in one colony, the average being 8.5 per cent. In the 10 soldier colonies, on the contrary, soldier production was very low, 0 in 4 of them and from 0.5 to 1 per cent in the others. One possible explanation of these results is that soldiers are not as effective as nurses as are workers and that almost all individuals in the colonies developed, therefore, under suboptimal conditions and became workers instead of soldiers, for the same reasons as in a young or undernourished colony. As Gregg points out, the soldiers did not appear in most cases until after there were numerous workers in the colony. The number which did appear is so small, however, as to weaken the significance of the time of their appearance. However this may be, Gregg's excellent study adds to the growing evidence for the theory that any young female larva is capable of producing any of the female castes, depending on the conditions at critical moments of development. The same may be said, of course, of the findings of Wesson and of Goetsch.

Gregg's results indicated a tendency toward regulation of the colonies experimentally altered as to caste composition to something approximating the statistically normal proportion of soldiers. From the data given by Gregg, it appears that while the ratio between workers and soldiers varies enormously in individual colonies in nature, the average proportion of workers seems fairly definite, both for the species used by him and for the other species of the genus *Pheidole* investigated by him. His 6 control colonies averaged 86 per cent workers at the end of the experiment, 16 other colonies of the same species averaged 81.9 per cent workers, and a somewhat similar figure was found for 29 colonies of *Pheidole bicarinata* (89.24 per cent) and for *P. pilifera* (88.5 per cent). A shift in composition of the worker colonies would result naturally from the fact that soldiers were produced in considerable numbers. Actually a somewhat larger number of soldiers was produced in them (an average of 8.5 per cent) than was produced in the control colonies (7.3 per cent). If this increased soldier production in worker colonies is significant it may be explained on the basis of the optimal conditions found in these well-fed colonies with plenty of workers. An alternate hypothesis would be that more soldiers were produced because of freedom from an inhibiting effect exerted by soldiers. The shift toward normal composition in the soldier colonies occurred, of course, because, while almost no soldiers were produced, numerous workers were. The lack of soldier production here may be explained, as noted above, as being due in part at least to the unfavorable conditions arising from the absence of workers, or as Gregg postulates, as being a direct result of inhibition arising from the presence of numerous soldiers.

Perusal of Gregg's figures reveals that the size of the brood produced by different colonies varied greatly. If we ignore two small colonies which died out, the range in size of brood produced for his worker colonies is seen to be 122 to 1135. Further, of the two largest broods produced by his worker colonies one was produced by a colony starting with 60 workers, the other by one starting with 2,008 workers. Perhaps no correlation between size of colony and size of brood is to be expected. Even so, the discrepancies in size of brood remain unexplained.

Finally, such data as are given indicate that

there was a very high mortality during the experiment and that the incidence of mortality by colonies was by no means consistent. These are situations all too familiar to the laboratory student of termites and suggest the existence of undefined variables affecting the results. I present these features of Gregg's results not as criticisms but to emphasize the necessity for great caution in evaluating the data derived from laboratory studies of social insects under existing laboratory methods.

DETERMINATION OF CASTES IN TERMITES

Smeathman's remarkably accurate account of the colonies and communal structures of tropical termites (1778) gave the first clear picture of the facts of polymorphism and social organization in the termites. For more than another century, however, the study of the termite castes remained in the observational and speculative stage. During this period the most noteworthy contributions were those of Lespes (1856) and Fritz Müller (1873 *et seq.*). Grassi's classic studies (Grassi and Sandias, 1893, 1894; English translation, 1897, 1898) furnished the first experimental results and laid an excellent basis for future studies. In the half century since then numerous students have attacked the problems of caste determination and an extensive literature has arisen.

Here, as with the ants, two theories have long been in opposition. The so-called blastogenic theory holds that the different castes appear as a result of intrinsic, that is genetic, differences in the eggs (Bugnion, 1912a, 1913; Imms, 1919; Thompson, 1917, 1919, 1922; Thompson and Snyder, 1919, 1920; Snyder, 1925, 1926; Bathellier, 1927). The somatogenic theory, on the other hand, holds that all eggs and early nymphs are alike and that their ultimate fate is determined by environmental influences (Grassi and Sandias; Heath, 1927, 1931; Kalshoven, 1930; Weyer, 1930, 1931; Pickens, 1932, 1934; Castle, 1934a, b; Hare, 1934; Goetsch, 1936, 1939; Miller, 1942). In addition, important contributions have been made by Emerson (1926, 1939a, b) and Adamson (1940).

The blastogenic theory received factual support from two sources. First, Bugnion (1912, 1913) reported finding newly hatched nymphs (larvae in European usage) of a nasute species in which the nasus of the soldier was already differentiated. This report was discredited by Thompson (1919) on the basis of earlier work by Knower (1894) and her own findings, and also by John (1925), who reinvestigated the species studied by Bugnion. Second was the seemingly careful work of Thompson (1917, 1919, 1922) in which she presented what appeared to be convincing evidence that in each of nine different genera of termites from three different families the nymphs of the first instar included two types of individuals, and that these types represented, respectively, those nymphs destined to develop into reproductives and those determined as sterile individuals.

The studies of Heath (1927) showed that Thompson's supposed types were not discernible in first-instar nymphs of *Zootermopsis* (formerly *Termopsis*). Weyer (1931) showed that the first-instar nymphs ("larvae") of three species of higher termites gave indications of a normal distribution of variation with regard to size of brain and head instead of falling into two types, and pointed out further that Thompson's data could not be properly evaluated, since no information was given as to the numbers of individuals measured nor the distribution of the different measurements. For these reasons he emphasized the necessity of completely disregarding both her evidence and any generalizations based on it.

Finally, Hare (1934), working with three American species of *Reticulitermes*, including the species studied by Thompson, and having access to the actual specimens studied by Thompson, concludes (1) that Thompson's supposed first stadium actually covered the first three stadia, (2) that within the true first instar the frequency scale of head width to brain width approximates a unimodal curve, (3) that there is little if any correlation between large gonad and small head-brain ratios, or vice versa, and (4) that not until a late stadium when certain individuals show wing buds can the nymphs of the sterile castes be separated from the alate line.

Thus fell away any factual evidence for a blastogenic theory of caste determination, leaving the field open once again and emphasizing the need for carefully controlled experimental studies.

Latest findings have emphasized the essential plasticity of the immature stages, as did the much earlier work of Grassi and Sandias and, more recently, that of Heath and Kalshoven. Kalshoven, like Heath, laid stress on the importance of the constitution of the group in determining the fate of individuals in it, and Castle (1934b) says of his own results, "Such vital modifications of individual development resulting from such slight changes in

colony composition illustrate the importance of individual interrelationships in maintaining the delicately balanced unity of a termite colony."

Even more recently, Miller (1942), in an excellent study of *Prorhinotermes simplex*, a primitive member of the family Rhinotermitidae, emphasizes the extreme plasticity of the nymphs. He finds that nymphs as late as the sixth instar are capable of becoming either soldiers or alates or of remaining as a doubtfully differentiated worker type.

My experiments with *Zootermopsis* have further emphasized this plasticity, indicating that it extends far beyond the sixth instar. Many of the large, broad-headed nymphs, termed soldier nymphs or, at times, soldiers by Heath (1927), are clearly of very late instar, some probably representing a tenth or even an eleventh stadium. These broad-headed nymphs are presumably capable of becoming ordinary apterous soldiers. Some of them, moreover, have wing rudiments, which may be lost or increased at subsequent molts. From such individuals, supposedly, arise some at least of the wing-padded soldiers occasionally encountered. The alate tendencies of these nymphs of advanced instar are in some instances, at least, carried to their ultimate conclusion and the nymphs become alates by a final molt (we have one authentic record). The alates with unusually large heads sometimes taken in flight may have this history. These alates would be in the tenth or eleventh instar, therefore, whereas Castle agrees with Heath that the alate stage is typically arrived at in the eighth instar. Another common history of these broad-headed nymphs is to become supplementary reproductives. Many broad-headed supplementaries are entirely apterous. Others have wing scars, or wing pads of varying size. Still others become the so-called fertile soldiers, or reproductive soldiers of Heath; actually, of course, these are supplementaries with more or less completely soldier-like heads.

It would seem most plausible to believe that the terminal types comprising alates, soldiers, workers where present, and individuals of precocious sexual maturity (neotenics) are end results of different developmental processes, each controlled by different genetic factors or patterns all of which are present in all individuals, and that the actual fate of each developing individual depends upon which of the several alternative genetic mechanisms comes into final play. Which of them does control the terminal developmental processes supposedly depends upon certain as yet unknown differential factors in that part of the complex environment, social or otherwise, experienced by the particular individual. Since all colonies develop all castes, these factors must be considered to be present at some times or places in all colonies. These differential factors, or influences, have been variously suggested to be parasitic castration (Grassi and Sandias), differential feeding (Grassi and Sandias; Jucci, 1920, 1924; Heath; and others), differential relations to oxygen supply (Weyer, 1931), ectohormonal inhibitions (Pickens, 1932; Castle, 1934a, b; Light, Hartman, and O. H. Emerson, 1937), or, more vaguely, "the constitution of the colony" (Kalshoven, 1930).

It must be repeated that the nature of the mechanisms which cause the appearance of the different castes in every colony of every species of termites still eludes us. Neither published results of recent investigations nor findings of an extensive program of experiments carried out under my direction during the past eight years, unpublished as yet but drawn on for this review, give final solutions. (The work under my direction has been carried out by a corps of assistants under the immediate supervision of a number of research assistants of whom I wish especially to mention here Mr. Paul Illg, in charge for the last two years and now assisting me in organizing the data.) They serve rather to render obvious the complexities of the situation under investigation, to extend the area of investigation and indicate promising points of attack, and to emphasize the difficulties and pitfalls involved in laboratory studies of social animals, the lack of uniformity in experimental results, the consequent difficulties in obtaining satisfactory controls and the caution which must be exercised, therefore, in drawing conclusions from the data thus obtained.

Knowledge of conditions among the social Hymenoptera, especially the bees, is widespread among biologists, and confusion often arises from the assumption that conditions in the termites are largely comparable to those in the bees and ants. Both the Isoptera and the social Hymenoptera, it is true, exhibit polymorphism, and in each we find sterile castes. Here the resemblance ceases, however. In other features of their social organization the Isoptera differ radically from the social Hymenoptera. It has seemed necessary, therefore, in order to insure a clear understanding of the problems presented by the termite colony, to

accentuate here the most important features in which the social organization of the termites differs from that of the social Hymenoptera. This has been attempted in the twelve numbered statements which follow.

1. Sexual dimorphism is negligible in the termites.
2. The primary reproductives of termites are considered to constitute a single caste, consisting of equal numbers of males and females.
3. The male termite, so far as is known, is diploid (Stevens, 1905; Benkert, 1930; Light and McAuley, MS) and is almost certainly bisexually produced.
4. Parthenogenetically produced termites are exclusively females and therefore probably diploid as to chromosomes (thelytokous parthenogenesis; see Vandel, 1927, 1936).
5. There is nothing in the termites to correspond to the haploid parthenogenesis of the male Hymenoptera.
6. The method of sex determination is presumably simpler in the termites than in the Hymenoptera. At least, nothing is found in them comparable to the sex-intergrades and sex mosaics common among the Hymenoptera.
7. The termite colony is completely bisexual, all immature stages and all castes consisting of approximately equal numbers of males and females. There is no counterpart, therefore, of the exclusively female castes of the Hymenoptera and, consequently, in termites sex determination has nothing to do with caste determination.
8. The male is fully functional in the social life of the termite colony. Termite colonies are gynandrarchic, founded and headed by male and female, usually by a single pair, both sexes assisting in founding the colony and caring for the eggs and first brood.
9. The flight of termites, although followed by pairing, is not a mating flight, as in the social Hymenoptera generally, nor a swarming flight as in the bees. Copulation does not occur until some time after pairing.
10. The sterile castes of the termites are by no means homologous with those of the social Hymenoptera.

Especially is it to be noted that the terms soldier and worker used in connection with both ants and termites have no significant common meaning for the two groups. Among termites the soldier caste is the older, nearly universal caste. The worker caste, on the other hand, is much more recent, being, in fact, a derivative of the soldier line (Emerson, 1926; Bathellier, 1927). The worker caste is altogether lacking in the large family of primitive termites, the Kalotermitidae, and has seemingly developed in the higher families since their separation from the lower families. Worker-soldier intergrades are practically unknown among termites, although neotenic soldier-nymphal intergrades occur commonly among lower termites.

11. The termites undergo long and gradual postembryonic development involving numerous immature instars separated by molts, thus making possible permanent arrest of growth at various stages of development, or development in different stadia along different lines; all of which makes for complicated and plastic polymorphism.
12. In lower termites all of the work of the colony is done by nymphs of various instars, and even in the higher termites they take part in it, whereas the social Hymenoptera, being holometabolous, their immature stages add to but do not partake in the communal tasks.

THE NON-REPRODUCTIVE CASTES

All termites possess one or more non-reproductive or sterile castes, individuals of which develop in all colonies in fairly regular numbers. The sterile individuals are of two basically different types: (1) workers which are distinctly nymphal, apterous, eyeless individuals, and (2) soldiers which have highly altered, heavily sclerotized heads, and whose mandibles are either enormously enlarged or vestigial. Commonly a species possesses a single caste of soldiers and, among higher termites, a single type of workers. In some species of higher termites, however, there are two or even three castes of soldiers and also of workers. In some instances these different types of soldiers and workers are size segregants, terminal in different instars; in others they show distinct qualitative as well as quantitative differences (Hare, 1931). Workers are less universal in occurrence than soldiers. They are lacking as a caste in the large primitive family, the Kalotermitidae, and their status is doubtful in the other two lower families. Even in the Rhinotermitidae the status of the

worker caste seems doubtful (Pickens, Ph.D. thesis; Miller, 1942). As to their phylogenetic origin I am in full agreement with Emerson (1926) that they represent a fixation of individuals (nymphs) in the line of soldier development. In two species of higher termites soldiers have been shown to arise, supposedly by two molts, from nymphs which are of nearly the same size as workers and which differ from workers only slightly, in pigmentation, etc. (Emerson, 1926, *Constrictotermes*; Bathellier, 1927, *Nasutitermes*). Presumably, therefore, in the Nasutitermitinae at least, workers become adult in what is equivalent either to the penultimate or the antepenultimate instar of soldier development.

Two mechanisms seem necessary to produce a definite worker caste. One would operate at a definite stage in development to prevent further molting on the part of the individuals affected, thus making them terminal individuals—adults in that no further growth occurs. It may be presumed that this influence comes to bear in the stadium preceding the definitive worker stadium, probably, therefore, in the equivalent of the antepenultimate stadium in soldier development in species having a single worker type. Presumably, therefore, some apterous nymphs of this stadium become soldiers by two further molts and others become workers following a single molt. The second mechanism which must be invoked is one which controls the development of (1) special pigmentation (or in rare instances of color patterns), (2) of increased sclerotization, and (3), in higher termites, of certain structural details of the nota, the palpi and the antennae, characteristic of workers as contrasted to all other individuals of the colony.

I know of no evidence as to the factors operating to regulate the occurrence of workers in the termite colony. Until further evidence is available, it would seem best to suppose for reasons appearing in the discussion of soldier determination that the control of worker development is a negative one, those apterous nymphs of higher termites inhibited from soldier development becoming workers.

It is customary to say that there is no worker caste among the Kalotermitidae and this usage is best maintained if the word caste is to retain a definite meaning. It must be remembered, however, that nymphs of various types and instars do all the work in these colonies except in the earliest stages of colony inception, when the founding reproductives are the effective workers. In *Zootermopsis* the nymphal stadia are numerous and long. Particularly important in these colonies are larger nymphs, typically apterous and therefore presumably in the soldier line. Many of these older apterous nymphs possess heads broader than those of the alate line and we have termed them broad-headed nymphs. Some of these must be in late instars, presumably the tenth or even the eleventh. It seems probable that we have here individuals which might well be considered to represent an incipient worker caste or at least to illustrate how such a caste may arise. Supposedly in the soldier line, they are in so late an instar that it seems unlikely they will or can molt into the soldier stage. That they are terminal cannot be proved, however, and indeed it is well known that they retain the ablity to develop into supplementary reproductives. Further, they develop wing pads in some instances and one at least in our cultures actually completed development into an alate. Here again we have exemplified the plasticity characteristic, at least of the lower termites, but not, apparently, of the higher termites where intercastes are rare (see Adamson 1940).

All termites except those of the genus *Anoplotermes* possess a characteristic soldier caste. This all but universal occurrence of soldiers seems to indicate that the ancestral termite stock already possessed such a caste. In line with its ancient status and in contrast to the recent essentially nymphal worker caste, the soldier caste is marked by a strikingly distinct morphology, especially as regards head and mandibles. The morphological changes from nymph to soldier are very great and occur over a considerable period involving two stadia. In the stadium intervening between the last two molts in soldier development the nymph is correctly designated an ultimate soldier nymph or simply soldier nymph, although the already enlarged head and mandibles give it an unmistakable soldier-like appearance. Because of its difference from ordinary nymphs and its resemblance to the soldier, the ultimate soldier nymph has been termed a pseudo-nymph by Kalshoven and a pseudo-soldier by Castle. This instar has not been recognized by all students of termites and has been confused by some with recently molted unpigmented definitive soldiers under the name of callow soldiers, a term which should properly apply only to the recently molted definitive soldier. The ultimate soldier nymph stadium is short, the individuals remain incompletely pigmented and

are not able to take food, and the stadium serves essentially as does the pupal stage in holometabolous insects.

While the absence of soldiers in *Anoplotermes* has been generally considered to be secondary, it has been supposed that the loss was a permanent one involving degeneration or loss of the genetic mechanism. Goetsch (1939) has reported, however, that soldiers developed in incipient laboratory colonies founded by primary reproductives of a species identified by von Rosen as belonging to *Anoplotermes*. The nasute soldier obtained by Goetsch is not the type to be expected in *Anoplotermes* on the basis of the relationships indicated by the morphological features of the genus, especially those indicated by the structure of the nymphal mandibles (Emerson *in litt.*; see also Hare, 1937). Goetsch does not state on what von Rosen's identification was based, and it seems best to withhold acceptance of an *Anoplotermes* soldier, therefore, until examination of the workers produced in these colonies, or of the actual primary reproductives heading the colony, settles their taxonomic status. Mixed swarms are common in the tropics and the specimens sent von Rosen may have been different from those which founded the colonies.

All students of incipient colonies report the occurrence of usually one or at most a very few soldiers in each first brood. Castle's experiments and my own (see below) show unmistakably that the introduction of a soldier into an incipient colony usually prevents the appearance of the expected soldier. If the presence of soldiers in an incipient colony tends to prevent nymphs from completing development into the definitive soldier, then the presence of soldiers may be supposed to regulate by inhibition the occurrence of soldiers in older colonies. On this hypothesis soldiers would be expected to appear with regularity in groups of nymphs separated from older colonies, providing they do not include soldiers. Both Grassi and Kalshoven found that soldiers develop in groups of isolated nymphs. Kalshoven noted, however, as did Grassi, that soldiers thus produced seemed usually not to be perfect soldiers and suggested that they were neotenic.

Miller (1942) sought experimental evidence as to the influence of the presence of soldiers in regulating the number of soldiers in groups or colonies. His data do not lend themselves to summarization, but I shall attempt to sample the most significant of his results. Of 807 wing-padded individuals set up in 21 groups without soldiers, 57 became soldiers, which was 18.5 per cent of the individuals which changed, whereas of 880 wing-padded individuals set up in 27 groups with soldiers, in a ratio of approximately 1 soldier to 3 wing-padded, only 6 became soldiers, or 2.5 per cent of the individuals which changed. In no group of the series with soldiers was more than one soldier produced, whereas of the 21 groups without soldiers 9 produced 2 or more soldiers (2 to 14). Miller (p. 26) concludes, with commendable caution, "The presence of adult soldiers in colonies of undifferentiated nymphs and of wing-padded forms had a slightly significant inhibiting influence on the development of additional soldiers."

In *Zootermopsis* I have found that soldiers very seldom occur in groups of nymphs isolated without soldiers, and at first sight this finding might seem to contradict the hypothesis that many nymphs tending to become soldiers are inhibited from further development in that direction by the presence of soldiers, or, conversely, that soldiers will shortly develop in groups lacking soldiers. Another explanation of these results seems more in line with facts, however. In groups of nymphs of *Zootermopsis* the tendency to neoteny is especially powerful, as will be seen later, and the individuals which most commonly become neotenic are just those nymphs, usually apterous, termed soldier-nymphs (or at times soldiers!) by Heath which could be expected to become soldiers. The onset of the shift toward precocious sexual maturity seems to arrest the individual in the instar in which it stands, or at most allows for but one molt (presumably when the individual is already near the molt). Thus perhaps, the neotenic drive supersedes in part at least the soldier drive, preventing soldier production in most groups. The so-called "nymphal soldiers" or "reproductive soldiers" which develop in some groups would seem to be well explained on this hypothesis being the result of the action of both drives in those individuals which were near the end of soldier development. As already noted, both Grassi and Kalshoven report deviation in the nymphal direction of soldiers produced under these conditions.

There seems to be no set proportion of soldiers in the colonies of *Zootermopsis nevadensis*. We have kept record for 74 colonies and find the percentage of soldiers to range from 0.49 to 12.49 per cent, with an average of 5.23 per cent. Grassi reported a ratio of 1 soldier to 5 nymphs in *Kalotermes flavi-*

collis. Miller found an even greater proportion of soldiers in *Prorhinotermes* (1:3.6 ± 0.55 in stock colonies).

TABLE 2

Occurrence of soldier flares in natural colonies

SIZE OF COLONY	MONTH	PER CENT OF PIGMENTED SOLDIERS	PER CENT OF CALLOW SOLDIERS AND SOLDIER NYMPHS	TOTAL PER CENT SOLDIERS
4347	January	2.50	2.90	5.40
3650	January	7.64	3.42	11.06
2213	February	6.32	6.06	12.38
4830	February	2.05	9.40	11.45
1973	March	2.30	2.00	4.30
3629	March	2.75	3.72	6.47
3312	April	0.84	2.99	3.83
843	May	0.95	3.67	4.62
2414	May	1.70	0.82	2.52
4375	June	1.83	1.83	3.66
1616	June	4.82	4.33	9.15
7000	June	2.40	1.11	3.51
2535	July	6.82	4.42	11.24
2500	October	2.08	3.28	5.36
4200	October	1.32	1.93	3.25

There should be noted here certain indications that soldier development is cyclic in *Zootermopsis*. Certain colonies are found to have great numbers of ultimate soldier nymphs and callow soldiers, indicating flares of soldier production in colonies. Our records indicate that such flares occur at different times during the year (see Table 2). Alates, although also seasonal in general, have been known to occur at almost all times of the year, and there is some evidence to indicate a correlation between these flares of soldier production and the presence of alates in the colony.

Neotenic nymphal-soldier intergrades, the so-called reproductive soldiers, have been mentioned. Intergrades between the soldier and alate castes do occur in termites. In one species, *Kalotermes occidentis* Walker, all soldiers are wing-padded and possessed of a compound eye larger than that common among the soldiers of primitive species. Wing-padded soldiers have been reported in other Kalotermitidae, but they are not the rule. In the Rhinotermitidae wing-padded soldiers have been reported for *Reticulitermes* by several authors (Grassi and Sandias; Pickens; Ghidini, 1938), and recently in *Prorhinotermes* by Miller. Such intercastes are evidently unusual among the higher termites, but Adamson (1940) reports them in *Microcerotermes arboreus* Emerson and *Nasutitermes guayanae* (Holmgren), and they may be expected to turn up in other species when these are carefully scrutinized.

A complication of the picture in *Zootermopsis* is the occurrence of wing-padded neotenic soldier-nymphal intergrades. Perhaps the soldiers of *Kalotermes occidentis* are not merely soldier-alate intercastes but supplementary reproductives. The rounded shape of the head in this species is suggestive of this but may be tied in with the alate influence.

(To be concluded)

CHEMISTRY OF "EYE COLOR HORMONES" OF DROSOPHILA

By BORIS EPHRUSSI

Department of Biology, Johns Hopkins University, Baltimore, Maryland

INTRODUCTION

ALL biologists are familiar with the statement that hereditary factors or genes control the development of hereditary traits or characters. How, by what mechanism, they achieve this control is one of the great unsolved problems of physiological genetics. In recent years attempts have been made to approach the solution of this problem from different angles. One of these attempts, the study of the mechanisms of the genetic control of eye color differentiation in *Drosophila*, has made particularly rapid advances since 1935. Several reviews have been published on the progress in this field (Beadle, 1937; Ephrussi, 1938; Becker, 1938; Beadle and Tatum, 1941). The purpose of the present article is to review a particular line of this work, namely, that which has led to the knowledge of the chemical nature of some gene-controlled substances intervening in the development of eye colors in *Drosophila* and representing, so to say, the intermediate links between the genes controlling their production and the final character.

In presenting the results of the work along this line, the author has chosen to follow, as closely as possible, the chronological order. It is indeed probable that, in adopting this order, the author, who has to a certain extent contributed to the development of the subject, was guided by a sentimental impulse. Whatever the reason, the author feels that for him this is the easiest way to tell an "eye-witness" story, in which a series of "lucky accidents" played as important a rôle as the logic of the planned experiments. This alternation of logical steps and of the unforeseen will be in many ways suggestive to the unspecialized reader.

From the latter point of view it is, no doubt, worth noting that the relatively rapid advances of the work related in this article has been, in a great measure, due to a frank and wholehearted cooperation between the different workers, particularly between the groups headed, at Stanford, by G. W. Beadle and, in Paris, by the present writer, and that, in this field of Biology, like in many others, the collaboration of biologists and chemists was a major factor in the achieved advances.

Vermilion in mosaics

The original facts which constitute the starting point of the work discussed in this review have been reported in 1920 by Sturtevant in a short paper published in the *Proceedings of the Society for Experimental Biology and Medicine*. In this paper Sturtevant has described the aberrant behavior of the mutant character vermilion in *Drosophila* gynandromorphs.

Gynandromorphs, that is, individuals composed of male and female parts, have been known in *Drosophila melanogaster* ever since this species has been extensively used in breeding experiments. Morgan and Bridges (1919) have made a detailed study of these exceptional individuals and have explained their origin through the elimination of one of the sex-chromosomes in the course of early cleavages. The study of sex-linked characters in these genetically mosaic individuals has shown that, as a general rule, "the male and female parts and their sex-linked characters are strictly self-determining, each part developing according to its own genetic constitution. No matter how large or small the region may be, it is not interfered with by influences coming from neighboring parts, nor is it overruled by the action of the gonads" (Morgan, Bridges and Sturtevant, 1925).

The aberrant case reported by Sturtevant in the above cited paper acknowledges the first exception to this general rule. A female heterozygous for the sex-linked genes eosin, ruby and forked was crossed with a male carrying in its X-chromosome the recessives scute, echinus, cut, garnet, vermilion and forked. Among the offspring of this cross a gynandromorph was found in which the male parts, including the head, showed the characters scute, echinus, cut, garnet and forked. The

female parts showed the forked character only. This appearance of the different parts of the fly was consistent with the interpretation that the animal started its development as a female carrying the maternal X-chromosome which was marked by the recessive genes listed above and that, in the course of one of the early cleavages, this chromosome was lost from one of the blastomeres, leaving the latter with the paternal X-chromosome only. However, on this interpretation, the eyes of the gynandromorph, whose head showed the paternal sex-linked characteristics, should show also the vermilion eye-color. This was not the case and from this observation Sturtevant has drawn the conclusion that "the non-vermilion color was then apparently determined not by the genetic constitution of the eye-pigment itself, but by some other portion of the body". Thus this short note contains the first description of a non-autonomous character in *Drosophila* and, in the quoted sentence, the first tacit assumption of the intervention of a diffusible substance in the process of eye color differentiation.

A similar behavior of vermilion was later observed by Bridges (1925) and L. V. Morgan (1929) in mosaics of different origin.

The importance of non-autonomous mendelian characters for the analysis of gene-controlled processes has been stressed by Sturtevant in his paper "The use of mosaics in the study of developmental effects of genes" read at the Sixth International Congress of Genetics (1932). In concluding this paper Sturtevant writes:

> It is clear that in most cases there is a chain of reactions between the direct activity of a gene and the end-product that the geneticist deals with as a character. One may surmise that any valid generalizations about these reactions are more likely to concern the initial links than the terminal ones. However, it is the terminal ones that are usually more open to experimental attack, since the only index to the effectiveness of a given experimental technique is the condition of the end product. Looked at from this point of view, the type of experiment that I have described may be considered as a beginning in the analysis of certain chains of reactions into their individual links.

This paragraph is quoted *in extenso* because it contains, along with a clear and concise definition of the purpose of Sturtevant's experiments (and of later work derived from these experiments), a precise statement of the methodological limitations involved.

Transplantation in Drosophila

Although Sturtevant's interpretation of the behavior of vermilion in mosaics implied a humoral correlation, the direct demonstration of the existence of hormone-like substances in *Drosophila* was provided only in 1935, with the introduction of a transplantation technique adapted to this species (technique described by Ephrussi and Beadle, 1936). One of the first experiments performed with the help of the new technique was, so to say, a duplication of the situation which arose spontaneously in the case observed by Sturtevant. Eye discs of vermilion larvae were transplanted into wild type larvae and it was found that, under these conditions, the vermilion eye discs developed into adult structures showing the wild type color (Ephrussi and Beadle, 1935; Beadle and Ephrussi, 1936). Since the implanted eyes developed in the abdomens of the hosts without any constant or very definite connections with the surrounding tissues, it was concluded from these experiments that the lymph of the wild type hosts contained a substance responsible for the observed change from vermilion to wild type. Vermilion, the first non-autonomous character known in *Drosophila*, was therefore interpreted as a deficiency for a specific substance. This substance, produced under the control of the wild type allelomorph of the vermilion gene, represents then a link connecting this gene with the corresponding character (Fig. 1, A and B).

Essentially similar results have been obtained by a German group of workers with an eye-color mutant in the moth, *Ephestia kuhniella* (Caspari, 1933; Kühn, Caspari and Plagge, 1935). In the following pages, however, the main emphasis will be placed on the work with *Drosophila* because the existence in this species of a considerable number of eye color mutants has made possible a much further analysis.

The confirmation of the non-autonomous nature of vermilion led to the search for other non-autonomous eye colors. Over two dozen *Drosophila* eye-color mutants have been tested by transplantation experiments similar to those used with vermilion. Eye discs of the different mutant types have been transplanted into wild type hosts and their color characteristics were examined after hatching of the flies. Among the various eye colors thus tested, another eye color, cinnabar, characterized by a similar vermilion-like pigmentation, was found to be also non-autonomous.

Cinnabar eye discs transplanted into wild type hosts differentiated into eyes with wild type color. Following the reasoning applied in the case of vermilion, the conclusion was drawn that the wild type lymph contains a substance responsible for the change of pigmentation of implanted cinnabar eyes. And thus the question arose whether the change from cinnabar to wild type was caused by the same substance which controlled the change from cinnabar to wild type. The wild type lymph contains both these substances. The lymph of the mutant cinnabar contains only one of them, namely the substance responsible for the change from vermilion to wild type. The mutant vermilion contains none of these substances. These two substances have been called respectively the v^+ and cn^+ substances or hormones, the exponent + indicating their occurrence in the lymph of animals

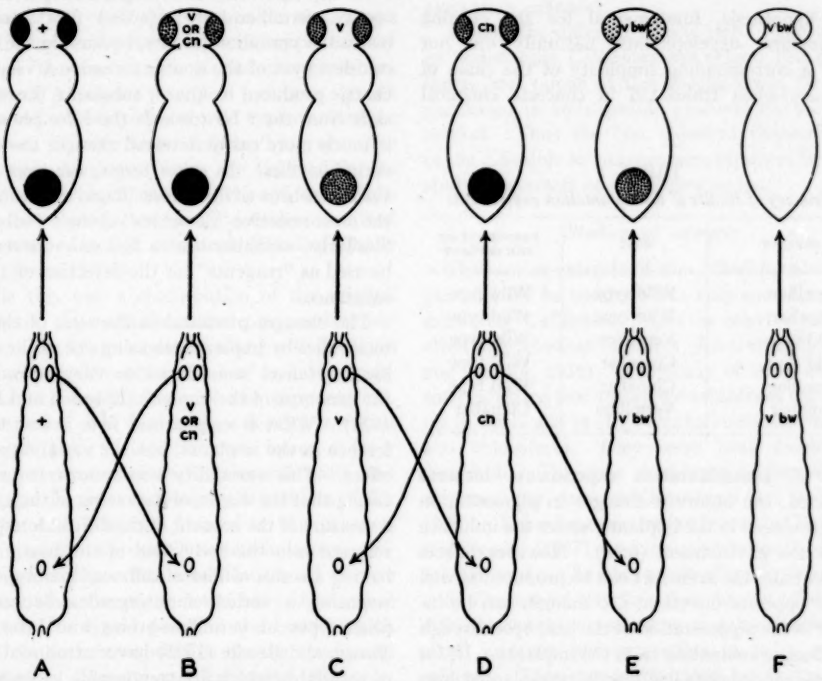


FIG. 1. SUMMARY OF THE RESULTS OF TRANSPLANTATION EXPERIMENTS
Below, host and donor larvae. Above, adult flies containing differentiated implants

from vermilion to wild type or whether the wild type lymph contained two different substances. The answer to this question was given by other transplantation experiments (compare A, B, C, and D of Fig. 1) whose results are summarized in Table I and among which the two reciprocal transplantations (5 and 6) between cinnabar and vermilion are particularly significant.

The results of these reciprocal transplantations make it quite obvious that there are two different substances, one responsible for the change from vermilion to wild type and the other for the change carrying the wild type allelomorphs of the genes vermilion (*v*) and cinnabar (*cn*) (Beadle and Ephrussi, 1936).

The above table contains only a few of the transplantations performed. In other transplantation experiments very numerous kinds of combinations have been realized between hosts and implants of different genetic constitutions. These experiments have lead to the important observation that, while a deficiency for the cn^+ substance alone characterizes the flies of certain genotypes, a deficiency or a decrease of concentration of the v^+ substance

is always accompanied by a deficiency or corresponding decrease of concentration of the cn^+ substance. On the basis of this observation the assumption was made by Beadle and Ephrussi (1936) that the two substances are formed in the course of a single chain of reactions, of which the v^+ substance represents the first and the cn^+ substance the second link:

$$\rightarrow v^+ \rightarrow cn^+$$

This hypothesis, fundamental for the ensuing experimental developments, naturally did not imply a corresponding simplicity of the chain of reactions when translated in concrete chemical terms.

TABLE 1

Summary of results of transplantation experiments

IMPLANT	HOST	PHENOTYPE OF THE IMPLANT
1. Vermilion.....	Wild type	Wild type
2. Cinnabar.....	Wild type	Wild type
3. Wild type.....	Vermilion	Wild type
4. Wild type.....	Cinnabar	Wild type
5. Vermilion.....	Cinnabar	Wild type
6. Cinnabar.....	Vermilion	Cinnabar

In all transplantation experiments hitherto described, the observed changes in pigmentation were produced in the implants, under the influence of the new environment (host). However, effects of essentially the same sort can be produced as well in the opposite direction, i.e. changes can be induced in the pigmentation of the host eyes through an influence emanating from the implants. If, for example, a cinnabar eye disc is transplanted into a vermilion-brown larva (the reasons for choosing this type of double recessive host will be explained in a moment), the eyes of the host, normally containing but traces of pigment, show a marked darkening (Fig. 1, E and F). This result has been interpreted as a case of release of the v^+ substance produced by the implant.

This type of effect is mentioned here not because it is thought that it represents, in itself, something essentially new, but for the following two reasons. First, because effects of this type and, especially, reciprocal effects of the host on the implant and of the implant on the host, within the same experimental animal, further support the formation of the v^+ and cn^+ substances in the sequence indicated above (see review by Beadle and Ephrussi, 1937); secondly and particularly, because of its technical value. The possibility of producing an effect on the eyes *in situ* has suggested a method for the detection of the diffusible substances in any material, for example in an extract. In other words, the finding of the effects on the hosts has supplied the basis for an assay technique indispensable in the early phases of all hormone work.

In the last mentioned experiment, double recessive vermilion-brown (*v bw*) flies were used instead of vermilion (*v*) flies, because in the almost colorless eyes of the double recessive a very slight change produced by the v^+ substance (i.e. a slight shift from the *v bw* towards the v^+bw phenotype) is much more easily detected than in the eyes of vermilion flies. In other terms, the eyes of the vermilion-brown flies were found to constitute the most sensitive "detectors" of the v^+ substance. Similarly, cinnabar-brown flies can conveniently be used as "reagents" for the detection of the cn^+ substance.

The changes produced in the eyes of these detector flies by implants releasing one of the diffusible substances were found to vary according to the genotype of the implant (Ephrussi and Beadle, 1937). What is emphasized here is not the difference in the implants, but the variability of the effect. This variability was interpreted as indicating that the degree of darkening of the eyes was a measure of the amount of the diffusible substance released into the body fluid of the host. By selecting a series of flies of different genotypes, representing a series of intergrades between the phenotypes of vermilion-brown and brown flies, Tatum and Beadle (1938) have introduced a scale of standards which are comparable to various degrees of modification of the eye-color of vermilion-brown flies under the influence of the v^+ substance and can be evaluated in terms of arbitrary color values. The comparison of an experimental fly with this scale of standards permits the description of the results in terms of these color values, assumed to be related to the amount of v^+ substance by approximate proportionality. One of the first steps of the eye color modification, corresponding to one of the lighter shades in the scale of standards, was taken as indicative of the action of one arbitrary hormone unit. Thus the method of detection of the v^+ substance was transformed into a method of semi-quantitative determination of the hormone.

Transfusion of lymph

As shown above, the existence of the diffusible (v^+ and cn^+) substances has been postulated on the basis of, and offered as an interpretation for, the non-autonomous or dependent differentiation of the color characteristics of certain eye implants. A necessary corollary of this interpretation is that the postulated substances are transmitted from the locus of their production to the reacting organs (host or implanted eyes) through the lymph. The demonstration of their presence in the lymph should therefore be regarded as a supplementary proof of the correctness of the interpretation. This proof has been provided by direct lymph transfusion. The lymph of wild type or cinnabar pupae was injected into "detector" larvae. The flies which developed from the injected larvae showed a clear modification of the eye color, indicating that the injected lymph actually contained the postulated active substance (Beadle, Clancy and Ephrussi, 1937).

While this was a confirmation of the original hypothesis, there still remained one possible objection. The lymph contains, along with its liquid phase, cellular elements which may be held responsible for the modifications of the pigmentation. This objection was met by experiments in which the lymph, prior to injection, was frozen at very low temperatures and thawed several times and centrifuged in order to remove the residues of the destroyed cells. Lymph treated in this manner, when injected into vermilion-brown larvae, produced nevertheless clear modifications of the eye color and thus the experiments have shown that it is really the liquid phase of the lymph which carried the factors responsible for the changes in pigmentation (Harnly and Ephrussi, 1937).

The results just described were the first real indication that it should be possible to isolate the active principles. Before this could be attempted efficiently, however, several purely practical difficulties had to be solved. As in all chemical studies of hormones, the location of the source of active material to be extracted was thought to be particularly important in view of the exceptionally small size of the flies which constitute the natural source of the diffusible substances. Therefore the search was undertaken for another rich and easily available source of the hormones. Extracts of different tissues of higher animals were examined but all gave negative results. Yeast extracts were negative also. Lymph of different insects (*Galleria melonella*, *Calliphora erythrocephala*, *Habrobracon juglandis*, *Ephestia kuhniella*, *Bombyx mori*, etc.) on the contrary, was found to contain substances which proved to be active in modifying the pigmentation in *Drosophila* (Ephrussi and Harnly, 1936; Beadle, Anderson and Maxwell, 1937). These experiments indicated then, in the first place, that the diffusible substances of *Drosophila* were not species-specific; secondly, they indicated a practical means for obtaining large quantities of extraction material.

Among the different insects rich in the v^+ and cn^+ substances, *Calliphora* was chosen, because the larvae and pupae of this species could be easily purchased in considerable amounts on the Paris market. Thus the first chemical characteristics of the diffusible substances were obtained from the study of extracts of *Calliphora* pupae.

Studies of extracts

That active extracts of the diffusible substances can actually be obtained was very soon shown by extracting *Calliphora* pupae in ethyl alcohol or ethyl alcohol-ether mixtures (Khouvine, Ephrussi and Harnly, 1936). The study of these extracts soon indicated that the active substances were soluble in water and in ethyl alcohol, insoluble in ether and chloroform. They were heat stable and dialysable. Therefore they were neither lipoids, enzymes, nor proteins (Khouvine and Ephrussi, 1937). These results were confirmed by Thimann and Beadle (1937) working with extracts of *Drosophila* pupae. Further study of both *Calliphora* and *Drosophila* extracts has shown that the diffusible substances are very unstable in acids and alkali and are not extractible in most organic solvents. They are precipitated by lead acetate and phosphotungstic acid as well as by Neubergs' reagent considered to be specific for amino-acids (Khouvine, Ephrussi and Chevais, 1938; Tatum and Beadle, 1938). Finally, the study of their rate of diffusion in agar blocks has indicated a molecular weight of 400–500 (Tatum and Beadle, *l.c.*). It should be pointed out here that throughout all these experiments the behavior of the v^+ and cn^+ substances and their properties appeared strictly identical and no separation of them has been possible.

Taken together, the results of all these studies have suggested the amino-acid like nature of the eye-color hormones and from this point on their further purification and eventual crystallization

was attempted. This line of work, however, has not led to the final identification of their chemical structure. While the results of the chemical work described above have played an important rôle in orienting the experiments which finally gave the clue, these experiments, as will be shown, were suggested by a different line of work.

Feeding experiments

In 1937 it was found that the diffusible substances will produce their effects on sensitive hosts not only when injected into the blood stream but also when administered *per os* (Beadle and Law, 1938). Since at that time it was already supposed, on the basis of the chemical investigations summarized above, that the active substances were amino-acids, it was realized that the "feeding technique" offered the possibility of testing various pure amino-acids or their mixtures for their hormone activity on a scale which was not accessible so long as it was necessary to resort to injections. Experiments were consequently started in which *Drosophila* (vermilion brown) larvae were raised on mixtures of agar, glucose and different amino-acids. It was assumed that these media would be sufficiently nutritive to support the completion of the growth and differentiation of larvae which, prior to the experiment (up to a certain rather advanced stage) were grown under standard food conditions. This assumption, however, appeared to be erroneous. In the first experiments only a low per cent of the larvae reached and went through metamorphosis. Only a few flies hatched, in a few of the experimental vials, and all these flies were of a very small size as a result of food insufficiency. However, the experiment led to an interesting observation. In one of the vials some flies developed a modified eye color, similar to that produced by a low dose of the v^+ substance. Was the amino-acid added to the medium in this vial responsible for the change? This was not certain since none of the control flies, raised on the agar glucose mixture without addition of amino acids, reached emergence. The repetition of the experiment on a large scale soon showed that this was not the case. In this new experiment eye color modifications were again observed, but they were observed in several vials containing very different amino acids. This pointed to the conclusion that the added amino acids were not involved at all in the observed effects. As a matter of fact, in this second experiment, some control flies did hatch on a medium containing no added amino-acids, and these flies showed the eye color modification as well. Were then the observed effects due to some impurity in the agar or in the glucose? Control experiments were performed which showed conclusively that the eye color changes could not be ascribed to any one of the constituents of the medium and suggested that they were induced by the general malnutrition of the larvae (Khouvine, Ephrussi and Chevais, 1938). Special experiments performed in order to test this conclusion have shown that partial or total starvation of vermilion-brown larvae will produce the change from v towards v^+, or, in other words, that under the influence of a certain diet, vermilion larvae, normally characterized by the inability to produce the v^+ substance, will be induced to produce it (Khouvine, Ephrussi and Chevais, *l.c.*; Beadle, Tatum and Clancy, 1938). This conclusion has been further confirmed by direct extraction of the v^+ substance from starved vermilion-brown larvae (Beadle, Tatum and Clancy, *l.c.*). Thus a very interesting relationship between the production of the v^+ substance and the general (probably protein) metabolism of the flies has been established. This relationship is an interesting problem of its own, but has no direct connection with the problem discussed here except for the practical conclusion concerning the feeding technique which had to be drawn from the results of these experiments. This conclusion pointed to the necessity of first working out an adequate nutritive medium into which the substances to be tested could be incorporated.

The effect of tryptophane

Among the different substances tested for their nutritive value, a peptone was tested and, while it appeared to be entirely satisfactory in so far as the general growth of the flies was concerned, its assay brought up a new and surprising result. Vermilion-brown flies raised on the medium containing the peptone also showed a modification of the eye-color, similar to that produced by starvation or by the addition of v^+ substance. In this case, however, the effect could hardly be attributed to a deficient diet and therefore seemed rather to indicate really the presence of an active principle in the peptone tested. Consequently experiments of the same type were repeated using several samples of peptones of different origins and various

proteoses. These experiments gave a very interesting result, namely that all the peptones tested, except one, gave positive results. The exceptional peptone was gelatin peptone which, as is well known, is characterized by the absence of tyrosin and tryptophane. The next obvious step then was the addition of tyrosin and tryptophane or their mixtures to the medium containing gelatine peptone. These experiments showed conclusively that tryptophane was the substance responsible for the eye color change.

But was tryptophane to be regarded as the v^+ substance? By definition, the v^+ hormone is a substance producing its characteristic effect when injected into the blood-stream. Tryptophane, however, when tested by injection, gave negative results. It became clear therefore that, while tryptophane could probably be regarded as a precursor of the v^+ substance, it could not be considered as being the substance itself. In other words, this finding made it quite probable that the v^+ hormone was a derivative of tryptophane. Consequently experiments were started in order to test the activity of various products of tryptophane transformation, both by feeding them to and injecting them into vermilion-brown larvae. This work has led to the finding of many tryptophane compounds active in the same way as tryptophane but inactive by injection (Khouvine and Ephrussi, unpublished). The work along this line has, however, been interrupted by the war and the decisive developments came from the combined results of two different lines of work, both starting from the discovery of the rôle of tryptophane in the described effects.

Bacterial synthesis of the v^+ substance

Throughout the experiments thus far described no particular attempt was made to control the growth of microorganisms in the media tested. In 1938 Tatum became interested in the nutritional requirements of *Drosophila* larvae and in connection with this work (Tatum, 1939b, 1941) established a technique for growing flies aseptically (technique described in Tatum and Beadle, 1939). One of the results of these studies of larval nutrition was the finding that media such as the agar-peptone mixtures used by Khouvine, Ephrussi and Chevais cannot support, under aseptic conditions, the normal growth and development of *Drosophila* larvae. The normal development of the flies in the experiments of these authors appeared therefore as probably due to the growth of microorganisms in these, by themselves deficient, media. If so, the hormone-like effects of starvation, peptones and tryptophane may have been due also to the intervention of microorganisms. With this idea in mind, Tatum and Beadle (1939) reinvestigated, under aseptic conditions, the effects of starvation peptones and tryptophane. While it was found that the starvation effect can be observed on flies grown under aseptic conditions, it appeared that the effect of tryptophane does not occur in the absence of microorganisms. The latter two effects were thus due to the presence of bacteria or yeast. In the course of these experiments, however, Tatum (1939a) found one vial accidentally contaminated by an aerobic bacillus. The vermilion-brown flies hatched in this vial showed a marked eye color modification. A culture of this unidentified *Bacillus* sp. was isolated from the contaminated vial and it was soon shown that the bacillus, when grown on a tryptophane-containing medium, synthetizes a substance similar in its effects and properties to the v^+ substance. The substance can be added to normal (complete) nutritive media and will produce the same effect. It therefore is clear that starvation plays no rôle in these results. Moreover, the substance extracted from the agar medium on which pure cultures of the bacillus were grown, was found to be active also when injected into vermilion-brown larvae. The method of extraction from the agar-medium showed that the solubilities of the active substance were similar to those ascribed to the v^+ substance on the basis of the chemical work related above. Finally, it should be mentioned that this substance produced effects only on vermilion-brown, not on cinnabar-brown flies. But Tatum (*l.c.*) was able to show that, like the v^+ substance, the substance obtained from bacterial synthesis, is converted, within the animal, to cn^+ substance. If vermilion-brown larvae, fed on a medium containing the substance synthetized by *Bacillus sp.* are, after pupation, boiled, crushed and fed to cinnabar-brown larvae, the latter develop into flies with a clearly modified eye color. Thus, the substance synthetized by Tatum's bacillus had all the known attributes of the v^+ hormone. Their identification required, however, their isolation in a pure state. The next step in the direction of this identification was made by Tatum and Beadle in 1940 when they succeeded in crystallizing the product of bacterial synthesis. On

the results of this work the authors report in the following terms:

... "This bacterially produced v^+ hormone has now been obtained in a pure crystalline state. The bacteria were grown on an agar medium containing dead yeast, sugar and l-tryptophane. The agar and yeast were precipitated in 80 per cent alcohol. The hormone was then taken up in a mixture of butyl alcohol, ethyl alcohol and water, and was finally precipitated from absolute butyl alcohol. It was then crystallized from 90 per cent ethyl alcohol. The crystals are very light yellow, elongated plates, usually forming in rosettes. The elementary analysis (made under the direction of Dr. A. J. Haagen Smit, of the California Institute of Technology) supports the empirical formula $C_{21}H_{34}N_2O_{14}$." (Tatum and Beadle, 1940).

It should be added that according to data of Tatum and Beadle one gram of this crystalline material will change from vermilion to wild type approximately one million flies.

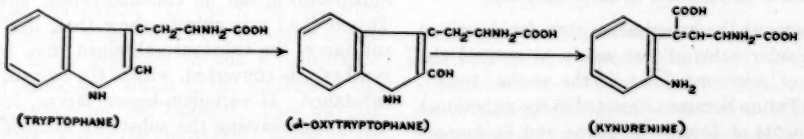
The identification of the v^+substance with kynurenine

The knowledge of the structural formula of the v^+ substance, however, is connected with still another line of work and due to another group of workers. When the relation of the v^+ substance with tryptophane was established, tests of the activity of various tryptophane derivatives have been performed by Butenandt and his coworkers in Berlin. Among the substances tested, kynurenine, a substance discovered by Kotake in the urine of rabbits fed on l-tryptophane, gave positive results, both by the feeding and injection tests (Butenandt, Weidel and Becker, 1940a). Thus kynurenine was the first pure chemical of known activity and isolated from bacterial synthesis is a sucrose ester of l-kynurenine.

The final proof of the identity of a chemically defined compound with the v^+ substance, however, should necessarily involve the demonstration of (1) the presence of the substance in flies which, according to transplantation experiments, contain it and (2) its absence in the mutant vermilion. Kikkawa (1941) has undertaken this work using the Otani-Honda method for the demonstration of kynurenine. The results of Kikkawa's work can be summarized as follows. Kynurenine can be detected in the mutant cinnabar and in its equivalent (mutant white-I) in *Bombyx*. From the eggs of the latter kynurenine sulphate has been obtained in crystalline form and shown to be active when injected into vermilion-brown *Drosophila* larvae. Tests for kynurenine in vermilion larvae and pupae are negative. Thus the first two criteria of the identification of kynurenine with the v^+ substance were fulfilled. However, the tests for kynurenine in wild type larvae and pupae were negative, while the original scheme of Beadle and Ephrussi calls for the presence of the v^+ substance in wild type lymph. Kikkawa assumes that these negative results are due to the rapid conversion of kynurenine into cn^+ substance (which is the compound responsible for the eye color change) and thus reconciles the scheme of Beadle and Ephrussi with the observed distribution of kynurenine.

The two remaining questions for which at least a partial answer can be given at present are those concerned with the origin and the fate of kynurenine.

According to Kotake, kynurenine is derived from tryptophane via α-oxy-tryptophane:



constitution whose physiological effects were found to be similar to those of the v^+ substance. The properties of kynurenine solutions are also similar to those of the highly active and highly purified solutions of the v^+ substance obtained from fly extracts. The results of Butenandt, Weidel and Becker made it very probable that kynurenine should be identified with the v^+ substance. This impression was further strengthened by the work of Tatum and Haagen Smit (1941) who were able to show that the crystalline product having v^+ This substance was only recently isolated by Wieland and Witkop (1940) from hydrolized phalloidin. Butenandt, Weidel and Becker (1940b) have injected solutions of α-oxy-tryptophane into vermilion-brown larvae and obtained positive, although weaker results than by injecting equivalent concentrations of kynurenine. It can be considered therefore that kynurenine arises from tryptophane via α-oxy-tryptophane *in vivo* also and α-oxy-tryptophane can be regarded as a precursor of kynurenine.

The nature of the cn⁺ substance

Since the cn⁺ substance is known to be derived from the v⁺ substance and since the chemical nature of the latter seems to be established, it should be possible now to gain some insight into, if not determine the nature of, the cn⁺ substance also. The most natural idea is to look for substances having a cn⁺ activity among the derivatives of kynurenine.

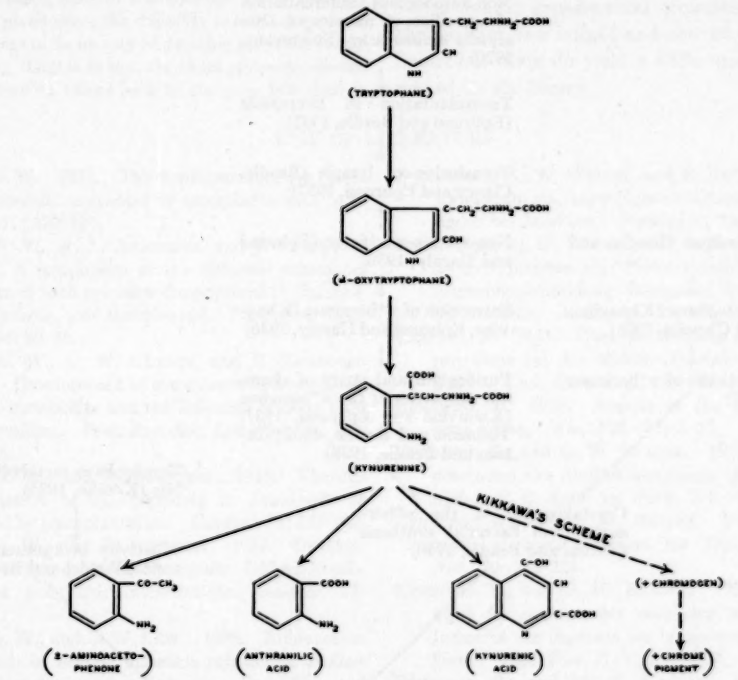


FIG. 2. THE PRODUCTS OF TRYPTOPHANE METABOLISM AND KIKKAWA'S SCHEME OF PIGMENT PRODUCTION IN DROSOPHILA

According to Kotake, in the animal body the transformations of kynurenine most commonly lead, through kynurenine-yellow, to o-amino-acetophenone, anthranilic acid and kynurenic acid (Fig. 2). The solubilities of the three first named substances suggest that they cannot be the cn⁺ substance. Injections of anthranilic acid by Kikkawa (*l.c.*) in fact gave negative results. Kynurenic acid, as well as α-decarboxykynurenine have been tested by Butenandt, Weidel and Becker (1940b) and did not show any cn⁺ activity.

Kotake has also suggested that the so-called Weiss urochromogen and the Sachs color substance, both found in human urine and responsible for Ehrlich's diazo-reaction, are derived from kynurenine. Although the solubilities of these substances are known to be different from those of the cn⁺ substance, Kikkawa has applied the diazo-reaction to the mutants of *Drosophila* and *Bombyx* in which transplantation experiments have demonstrated the presence or the absence of the cn⁺ substance. These tests have shown that there is a clear correlation between the presence of the cn⁺ substance and a positive diazo-reaction. Kikkawa further shows that the diazo-reaction, negative in vermilion-brown controls, becomes positive if the larvae are grown on a medium to which kynurenine has been added. In other words there is an identity of distribution of the cn⁺ substance and of a factor responsible for a positive diazo-test, and a causal relationship between the latter and kynurenine. From the above identity of distribution Kikkawa concludes that the cn⁺ hormone is the substance responsible for the positive diazo-reaction. He calls it the "+

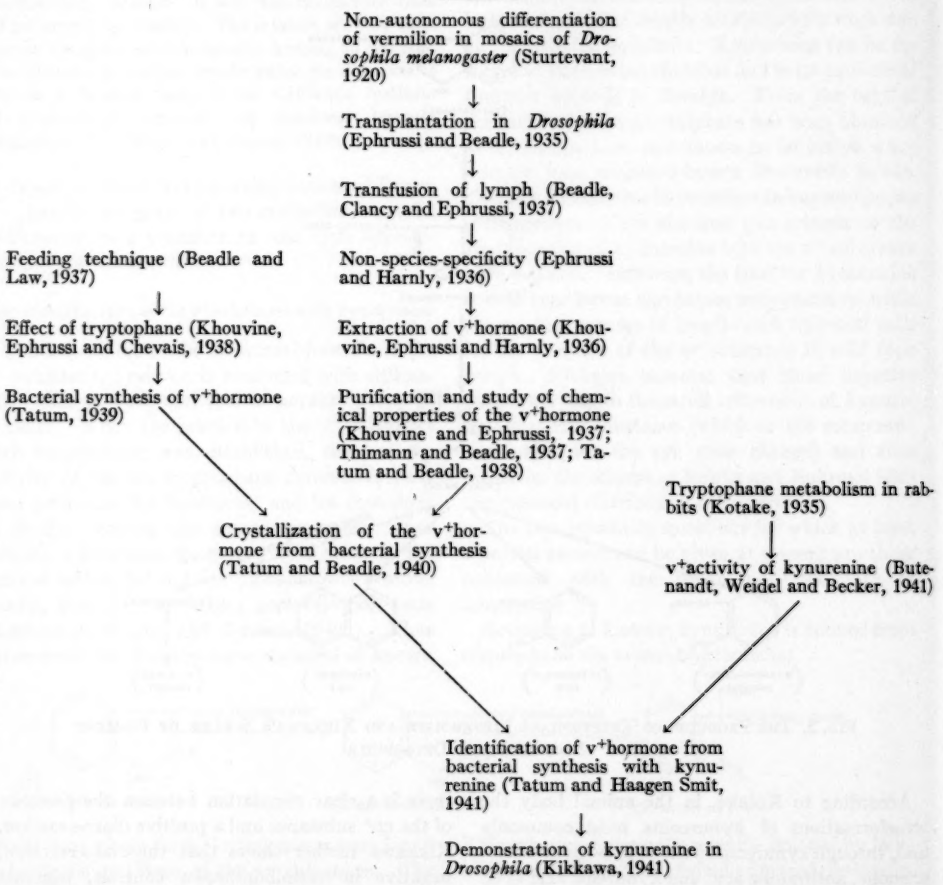
chromogen", thus indicating by the new term that the cn^+ substance is a direct precursor of the pigment.

PERSPECTIVES

The work of Kikkawa brings the story of the eye-color hormones of *Drosophila* up to date. Starting from the results of transplantation experiments which led to the postulation of the formation in sequence of two diffusible substances representing the first known links in the chain of reactions connecting the genotype with the character, we have now reached the point where a part of this chain can be described in chemical terms (Table 2 recapitulates the obtained results). The task of the future will be to connect these intermediate links with the two opposite ends of the chain.

The relation of kynurenine and of the cn^+ substance to the pigment is by no means clear, although Kikkawa, as mentioned above, assumes the cn^+ substance to be a precursor of pigment. Here, however, no major difficulty seems to stand in the way of future progress.

TABLE 2


Non-autonomous differentiation of vermilion in mosaics of *Drosophila melanogaster* (Sturtevant, 1920)
Transplantation in *Drosophila* (Ephrussi and Beadle, 1935)
Transfusion of lymph (Beadle, Clancy and Ephrussi, 1937)
Feeding technique (Beadle and Law, 1937)
Non-species-specificity (Ephrussi and Harnly, 1936)
Effect of tryptophane (Khouvine, Ephrussi and Chevais, 1938)
Extraction of v⁺hormone (Khouvine, Ephrussi and Harnly, 1936)
Bacterial synthesis of v⁺hormone (Tatum, 1939)
Purification and study of chemical properties of the v⁺hormone (Khouvine and Ephrussi, 1937; Thimann and Beadle, 1937; Tatum and Beadle, 1938)
Tryptophane metabolism in rabbits (Kotake, 1935)
Crystallization of the v⁺hormone from bacterial synthesis (Tatum and Beadle, 1940)
v⁺activity of kynurenine (Butenandt, Weidel and Becker, 1941)
Identification of v⁺hormone from bacterial synthesis with kynurenine (Tatum and Haagen Smit, 1941)
Demonstration of kynurenine in *Drosophila* (Kikkawa, 1941)

Bridging the gap between the hormone-like substances which, at the present stage, are the first tangible manifestations of certain genes, with these genes, promises to be a much harder task. What is known at present of the action of the v^+ gene indeed suggests that this gene intervenes in the tryptophane metabolism by producing a spe-

cific oxidizing enzyme. Thus the problem of primary gene activity in this case seems to resolve itself into a problem of enzyme chemistry.

In so far as the primary genic action is concerned, however, we are confronted with more than purely practical difficulties. As Sturtevant (1941) puts it in discussing the methods of physiological genetics in a recent article:

"there is no *a priori* reason why the method may not, in certain cases, lead to a knowledge of the primary effect of a given gene; the difficulty is that, at present, there appears to be no way of deciding the point in any given case. That is to say, the chain of developmental reactions may be traced back to the gene, but there is no way of determining when one has reached the gene" (p. 48).

The theoretical difficulty pointed out by Sturtevant is very real indeed. The present writer does not think, however, that the efforts along the same path should be abandoned. Instructed by the lessons of past experience and without underestimating the value of scientific planning, he keeps his optimism unaltered. It is his belief that unpredictable experimental situations often are the seeds of new insight and new ways of attack. Sometimes they do yield a little more than permitted by the theory.

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DEVELOPMENTAL PROCESSES AND ENERGETICS
(*Concluded*)

By ALBERT TYLER

William G. Kerckhoff Laboratories of the Biological Sciences
California Institute of Technology
Pasadena, California

III. EVIDENCE OF ENERGY REQUIREMENTS

6. Respiration and rate of development of dwarf embryos

UNDER ordinary conditions the oxygen consumption may be taken as a measure of the energy turnover of the embryo. On this basis then two dwarf embryos should show a greater total oxygen consumption than one normal embryo when corresponding stages of development are attained. This increase could result from an increased *rate* of oxygen consumption while the rate of development remained the same, or it could result from a slower rate of development on the part of the dwarfs while the rate of oxygen consumption remained the same as in the normal embryos. The experiments show that the latter is the case.

The dwarfs in these experiments were produced by isolating the blastomeres in the two-cell stage of the sea-urchin egg. By suitable technique sufficient quantities of embryos could be obtained for the respiration measurements. As the data in Table 2 show, the rate of oxygen consumption (per mg. Kjeldahl nitrogen) of the dwarf embryos does not differ significantly from that of the normal embryos. This means that in the same time interval two dwarf embryos consume as much oxygen as one normal embryo. The dwarf embryos develop, however, at a much slower rate than the normal. They begin gastrulation at the normal time (at about 19 hours in *Echinus* at room temperature) but complete it and pass through later stages at a much slower rate than the controls. The delay in rate of development amounts to about 30 to 40 per cent. For example, in one experiment it took about five and a half hours for the dwarfs to complete gastulation as compared with four hours in the controls.

Since oxygen consumption goes on at the normal rate in the dwarf embryos, and the rate of development is slower, then, to reach the same stage of development, two dwarfs will consume more oxygen than one normal embryo. The increased oxygen consumption would amount to about 35 per cent if we take the beginning of gastrulation as a starting point. The expected value for the increased energy requirement (see above) is 41 per cent on the basis of a linear relation between force and wall thickness. Too much significance need not be attached to the actual figures at present.

TABLE 2

Rate of oxygen consumption of dwarf embryos of the sea-urchin

(After Tyler, 1933.)

EXPERIMENT	AGE OF EMBRYOS IN HOURS	RATE OF OXYGEN CONSUMPTION IN CU. MM. O_2 PER HOUR PER MG. KJELDAHL NITROGEN	
		Dwarf	Normal
A	15	21.2	20.7, 21.5
B	19	26.7	27.1, 25.6
C	19	26.7	25.5, 25.9
D	19	27.9, 27.1	27.8, 26.9
E	20	26.7	26.9, 27.8
F	22	27.0	27.9, 26.2
G	24⅓	28.1	29.3, 28.3

The important point is that the dwarf embryos do manifest the expected increase in total oxygen consumption. It seems quite reasonable too that this should be done by a retardation in rate of development rather than an increase in rate of oxygen consumption. There is no reason to expect the separation of the two cells in the two-cell stage to cause them to spontaneously increase their rate of oxygen consumption (i.e. above the normal rise that accompanies development), especially as we know that the rate of diffusion of oxygen is not a limiting factor in the sea-urchin egg at ordinary oxygen tensions (Amberson, 1928; Gerard, 1931; Tang, 1933).

The slower development of dwarf embryos has often been noted (see Tyler, 1933, for references). It has generally been attributed to a process called regulation which is assumed to require time. According to the present interpretation regulation (or whatever one might call the process which enables each of the two cells of the two-cell stage, when separated, to produce a normal embryo) does not require time. If such a re-adjustment process exists, it must, according to our view, be instantaneous. The slower development of the dwarf is regarded as being due to its having more than the normal amount of work to perform (per unit mass) while the energy supplying reactions (as measured by the oxygen consumption) go on at the normal rate.

Dwarf embryos of quarter-size (i.e. from isolated blastomeres of the four-cell stage) develop more slowly than do dwarfs of half-size. This is to be expected on the basis of the present analysis, although one could invoke regulation (a greater time needed for the quarter-size dwarfs) to account for it. Another interesting case is that of the dwarfs of unequal size produced by Spemann and Falkenberg (1919) in the salamander. They found that the smaller of the pair of twins developed more slowly than the larger partner, and, rather than to invoke regulation, they suggested that the retardation might be connected with the smaller size.

On the other hand, Horstadius and Wolsky (1936) have found it necessary to use the concept of regulation time in some highly interesting work on bilateral symmetry in the sea-urchin egg. They present evidence for the existence of a bilateral organization of the egg in the early cleavage stages. In pairs of dwarf embryos that presumably come from separating the dorsal and ventral sides of the egg it is found that the dorso-ventral axis is inverted in the dorsal partner while it is unchanged in the ventral partner. Both develop into normal plutei. The dorsal partner, however, is observed to develop at a slower rate than the ventral dwarf, both developing slower than the whole embryo. The greater retardation on the part of the dorsal dwarf is interpreted as due to time being required for regulation. This difference is not exhibited by "right" and "left" partners, both being about equally retarded in comparison with the whole embryo. Horstadius and Wolsky are of the opinion that both factors, regulation time as well as the energy relations, may be involved in the retardation exhibited by the dwarf embryos, the two views not being mutually exclusive.

Horstadius and Wolsky also found that dwarf embryos of one-eighth the normal size could develop to the pluteus stage. Previous investigators have never been able to get embryos from isolated blastomeres of the eight-cell stage to go beyond gastrulation. As a possible explanation for this failure it was suggested (Tyler, 1935) that the available energy is used up in the early stages in performing the relatively increased work of differentiation in one-eighth-sized embryos. This was evidently an overstatement since it is now shown that the $\frac{1}{8}$ embryos can reach the pluteus stage. The necessary feature, according to Horstadius and Wolsky, is that the original fragments be composed of both animal and vegetal material of the egg, and this is accomplished by operating at the 32-cell stage instead of the eight-cell stage. It would, however, be of interest to know whether there are differences in diameter and thickness of wall in the beginning gastrula stage between the embryos obtained by these two methods. The finding that $\frac{1}{8}$ embryos can develop to the pluteus stage does not by any means conflict with our view, since all that we are justified in expecting is that they should develop more slowly than the $\frac{1}{4}$ embryos, if they bear the same dimensional relation to the whole embryo.

7. *Giant embryos*

The viewpoint that we have developed is further supported by the behavior of giant embryos. Driesch (1900) first showed that normal embryos of giant size could be obtained by the fusion of two fertilized eggs. On the assumption that time is required for regulation then the giant embryos should develop more slowly than the controls, since there must be at least as much regulation involved in the production of a single embryo from two eggs as in the production of two embryos from a single egg. On the other hand the expectation from the present analysis is that the giant embryos should develop more rapidly than the controls. Experiments undertaken to test this (Tyler, 1935) showed that the latter is the case.

The experiments were performed on eggs of three different species of sea-urchin. The eggs were fused in the one-, two-, or four-cell stage. Most of the fused eggs develop into double monsters of various sorts. Normal giant embryos were obtained from the fused eggs in fourteen cases. Ten of these developed faster than the controls and four developed at the same rate as the controls. None developed slower. The acceleration can be ob-

served in the gastrula stage as Fig. 2 illustrates. In later stages the difference in rate becomes more marked. Thus, in the case showing the biggest difference in rates, the giant completed gastrulation at 26 hours after fertilization as compared with 30 hours for the control, and entered the pluteus stage at 45 hours as compared with 64 hours for the control. The average for all the cases observed produced giant and dwarf embryos by cutting two beginning gastrulae of *Triton* parasagittally, one to the left, the other to the right of the mid-line, and fused the two larger pieces together as well as the two smaller pieces. In the cases in which both fused embryos developed normally, the giant embryo developed markedly faster than the dwarf embryo.

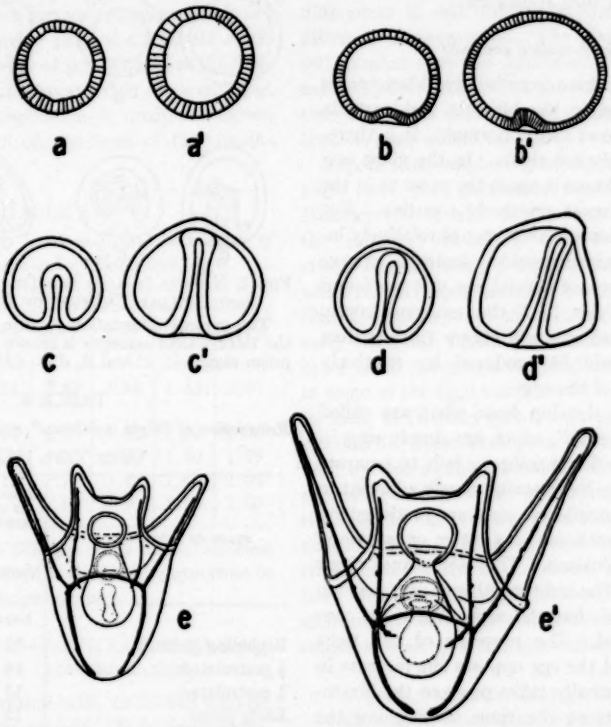

FIG. 2. NORMAL (a to e) AND GIANT (a′ to e′) SEA-URCHIN EMBRYOS OF IDENTICAL AGES

The more rapid development of the giants is manifest in the late gastrula and prism stages (c, c′ and d, d′). The plutei (e and e′) were drawn at 3½ days, but the giant entered this stage at 64 hours and the normal at 82 hours. (After Tyler, 1935.)

(including the four showing no increase) amounted to 1.4 times the control rate if the beginning of gastrulation is taken as the starting point. The number of cases is, of course, not sufficiently large to attach much quantitative significance to this value. The main point is that the giant embryos do develop more rapidly than the controls.

This more rapid development on the part of giant embryos was noted by Spemann and Bautzmann (1927) in some experiments on salamander eggs performed with other purposes in view. They

Another instance that may be cited is the faster development of giant limbs which Filatow (1932) observed. By grafting a limb-bud of one salamander embryo on to that of another embryo in the same stage a normal giant limb could be produced and it was found to differentiate more rapidly than the control limb on the unoperated side. This result, too, fits in with the view that there is relatively less work of differentiation in relation to the energy supplied in the case of the giant structure.

Filatow also produced giant eyes by fusing presumptive optic cup material. But in this instance no acceleration was observed; neither was there a retardation. The difference may be that the optic cup develops within the embryo and so the enlarged structure may encounter greater resistance on the part of the adjacent, normal-sized structures, whereas the limb grows out from the embryo and is relatively free of such resistance.

8. Thick-walled embryos

In the dwarf embryos from isolated blastomeres the wall thickness, in the blastula and gastrula stages, is the same as in the normal. It is therefore proportionately too thick. In the giant embryo the wall thickness is again the same as in the normal embryo, hence relatively too thin. For further investigation of this factor of relatively increased wall thickness it would be desirable to have thick-walled embryos of normal size. It was found in echinoderms (Tyler, 1937) that embryos having in the blastula and gastrula stages thicker than normal walls, could be produced by relatively simple treatment of the eggs.

These embryos develop from what are called "tight membrane eggs", which are simply eggs in which the fertilization membrane fails to separate off from the surface but remains closely adjacent to the egg. Tight membrane eggs are produced by short treatment with acid sea water or isosmotic non-electrolyte solutions. They sometimes occur spontaneously. The tight membrane eggs develop into normal plutei, but the early stages are considerably modified. The presence of the tight membrane around the egg opposes the increase in diameter that normally takes place as the blastocoel forms. Thus at the time of hatching the blastocoel is considerably smaller and the wall correspondingly thicker than normal. The difference is maintained through the gastrula stage, although both tight membrane embryos and normal embryos are continuously increasing in diameter and decreasing in wall thickness.

At gastrulation, then, the tight membrane embryo (Fig. 3b′) has a thicker wall than the control (Fig. 3b), but it is also smaller in diameter. It does not, therefore, quite meet the requirements we have set. We can, nevertheless, state our expectations as to its rate of development. Proceeding as before a normal embryo is compared with a hypothetical embryo of the same diameter as the tight membrane embryo but with a proportionately normal wall thickness. Then this hypothetical embryo is compared with the actual "tight membrane" embryo. Without going through the details it may be stated that for similar form changes (gastrulation, etc.) the "tight membrane" embryo should require more energy than the normal. If the rate of energy supply is the same in both then the "tight membrane" embryo should develop slower than the normal

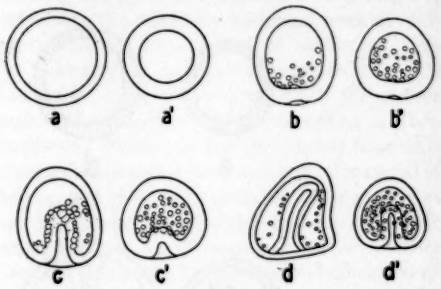

FIG. 3. NORMAL (a to d) AND THICK-WALLED (a′ to d′) SAND DOLLAR EMBRYOS OF IDENTICAL AGES

The typical retardation in rate of development of the thick-walled embryos is shown in the gastrula and prism stages (c, c′ and d, d′). (After Tyler, 1937.)

TABLE 3

Retardation of "tight membrane" embryos of Dendraster

(After Tyler, 1937.)

STAGE OF DEVELOPMENT	AVERAGE TIME OF DEVELOPMENT AT 20°C.		INCREASE IN TIME FROM THE BEGINNING OF GASTRULATION
	Normal	Tight membrane	
	hours	*hours*	*per cent*
Beginning gastrula	12	12	0
½ gastrulated	14	16	100
¾ gastrulated	15	19	133
Early prism	16	22	150
Late prism	21	26½	61
Early pluteus	23½	31	65
Late pluteus	52	68	40

This is in fact found to be the case. The tight membrane eggs show the same rate of respiration as the controls while they develop at a much slower rate. The retardation in development is illustrated in Fig. 3. Gastrulation begins at the same time in both but is completed much sooner in the normal embryo. The retardation is proportionately greater in the gastrula and early prism stages than in the later stages, as Table 3 shows. It

differs in this respect from the results with dwarf embryos where the retardation remains proportionately the same in all stages. This difference is probably due to the fact that the tight membrane egg finally attains, in the pluteus stage, the normal dimensions. There are other complicating factors in the "tight membrane" embryos such as the abnormal distribution of the mesenchyme cells which may have an effect on the rate of development. Until the effect of such factors are assessed it is not profitable to attempt to push the analysis much further. All we can say at present is that the finding that development is retarded in these embryos while the rate of respiration is unaltered agrees with the expectation on the basis of the dimensional reasoning.

TABLE 4

Temperature coefficients for cleavage and later stages of development of sand-dollar (Dendraster) eggs

(After Tyler, 1936a.)

	15.0°/25.0°	12.0°/22.0°	8.0°/18.0°	15.0°/20.0°	10.0°/15.0°
2-cell stage	2.21	2.82	3.88	1.62	2.01
4-, 8-, and 16-cell stages	2.24	2.80	3.82	1.60	1.96
Gastrulation	2.20	2.79	3.98	1.60	1.99
Prism	2.17	2.79	3.86	1.63	2.04
Pluteus		2.84	3.94	1.65	2.03

The figures give the averages of the ratio of the time to reach a particular stage at the lower temperature to the time at the higher temperature.

IV. EFFECT OF TEMPERATURE ON RATE OF CLEAVAGE AND RATE OF DIFFERENTIATION

Change in temperature will, as is well known, alter the rate of development. It is conceivable, then, that the processes of differentiation, growth and maintenance might be differently affected by change in temperature. But in experiments on the eggs of several marine animals (Tyler, 1936) no evidence was found of a differential effect. We assume as before that cleavage is an index of growth in the type of egg under consideration. The results show that change in temperature affects the rate of attainment of the various stages of differentiation to the same extent as it affects the rate of cleavage. This is illustrated in Table 4 for the eggs of the sand-dollar. The range of temperatures employed practically covers that in which development is normal. Similar results were obtained with the eggs of sea-urchins (*Strongylocentrotus* and *Lytechinus*), ascidians (*Ciona*) and worms (*Urechis*).

The results were checked in another way; namely, by determining the number of cells present in embryos reared at two different temperatures when identical stages of differentiation are attained. If cell division and differentiation are differently affected by temperature there should be differences in cell number in embryos raised at different temperatures. The determinations of cell number show no significant differences. We may conclude, then, that growth and differentiation cannot be dissociated by means of temperature, at least within the normal range.

Experiments employing supramaximal temperatures have been performed on frog embryos by Hoadley (1938) who also reviews earlier work on the subject. Among a number of interesting effects Hoadley notes a suppression of gastrulation while cell division continues (as evidenced by the resulting small cells) as a result of transferring early blastulae to the higher temperature. Another effect noted is a retarded utilization of yolk in some of the high temperature embryos. There is, then, as Hoadley points out, evidence that the various developmental processes may be dissociated by this means. Recently Ryan (1941b) has presented evidence that in the frog some dissociation can be effected by temperature within the normal range. He finds that the temperature coefficients for stages of embryo formation differ from those for cleavage stages, although the coefficients are constant within the various cleavage stages, as well as within the various later stages.

V. EFFECT OF TEMPERATURE ON RATE OF RESPIRATION AND RATE OF DEVELOPMENT

It is of interest to know whether the rate of respiration (which we assume measures the rate of energy supply) varies in the same way with change in temperature as does the rate of development. In the earlier work the results are conflicting. More recent experiments (Tyler, 1936; Atlas, 1938) show that the temperature coefficients for rate of respiration and rate of oxygen consumption are the same. This is illustrated in Table 5, which gives some of the data obtained with eggs of the sea-urchin. Identity of the temperature coefficients means that during the same developmental period at different temperatures there will be the same total oxygen consumption, and that is what the

figures in Table 5 show. Similar results are obtained with sand-dollar, worm, ascidian and frog eggs.

Regardless, then, of the temperature (within the normal range) an embryo will consume the same amount of oxygen in reaching a given stage of development. There is no optimum temperature at which development is accomplished with a minimum respiration.

The results may be interpreted to mean that change in temperature does not alter the proportions in which the available energy is utilized by maintenance, growth and differentiation, or that there are compensatory changes in the requirements for these processes. The latter seems unlikely but the possibility cannot be readily dismissed.

eggs do not differ significantly over most of the temperature range in which development occurs. At the lower temperature intervals there may in some cases be significant differences, but there are not sufficient data to determine this point. In the different species investigated the change in rate of respiration upon fertilization varies considerably, but this apparently bears no relation to the values of the temperature coefficients.

Bodine (1932) determined the temperature coefficients of the rate of oxygen consumption of diapause (resting) and developing grasshopper embryos. The rate of respiration is greatly reduced in the diapause stage as compared with the pre- or post-diapause stages, but the temperature coefficients are found to be the same.

The similarity of the temperature coefficients of

TABLE 5

Oxygen consumed by eggs and embryos of the sea-urchin (Strongylocentrotus) during the same developmental period at different temperatures

(After Tyler, 1936b.)

TIME AFTER FERTILIZATION AT START OF MEASUREMENTS	TEMPERATURES		RESPIRATION TIME		CU. MM. O_2 PER MG. EGG NITROGEN	
	Higher	Lower	Higher temp.	Lower temp.	Higher temp.	Lower temp.
	°C	°C	*hours*	*hours*		
45 minutes	20	15	1.0	1.36	6.7, 6.8	6.2, 6.6
35 minutes	20	10	1.0	2.3	6.4, 6.3	6.5, 6.1
50 minutes	20	7.5	1.0	3.2	6.4, 6.3	6.2, 6.3
18¾ hours	20	15	3.0	4.11	65, 67	68, 69
21¾ hours	20	15	3.0	4.11	72, 75	75, 77

The rate of respiration of unfertilized eggs is also known to vary with temperature. Since an unfertilized egg may be considered a resting cell it should exhibit simply maintenance (basal) metabolism. This does not mean that its respiratory rate should be lower than that of the fertilized egg. In fact Whitaker (1933) has shown that in some species the rate is higher before than after fertilization. We might, however, expect the temperature coefficients of the respiratory rate to be the same in unfertilized as in fertilized eggs. This was investigated in some experiments on marine eggs by Rubenstein and Gerard (1934) and by Tyler and Humason (1937). While there are differences in the results of the two sets of investigations that need yet to be resolved, we shall use the data of the latter investigators as a basis for discussion. Table 6 summarizes most of the data. The temperature coefficients of the resting and of the developing

TABLE 6

Temperature coefficients (average Q_{10}'s) for rate of oxygen consumption of resting and of developing eggs

(After Tyler and Humason, 1937.)

	TEMPERATURES	RESTING EGGS	DEVELOPING EGGS
Strongylocentrotus	22° and 12°C	2.54	2.4
	20° and 10°C	2.6	2.3
	18° and 8°C	2.6	2.6
	17.5° and 7.5°C	2.7	2.8
Urechis	22° and 12°C	2.6	2.7
	20° and 10°C	2.5	2.9
Ciona	25° and 15°C	1.9	2.2
	22° and 12°C	2.0	2.5
Dendraster	22° and 12°C	2.6	2.8

the respiratory rate in unfertilized and in fertilized eggs does not quite answer the question as to the possibility of compensating effects which was mentioned above. In adult physiology the maintenance (basal) metabolism is measured by the respiration or the heat production under "resting" conditions. It is tacitly assumed that the measurements give the amount of energy actually required under the particular conditions; that is, that there is an exact adjustment between requirement and production. It is difficult to regard the situation in any other way. An adjustment of this kind seems to be illustrated in muscle physiology by the "Fenn effect" (Hill, 1931). Fenn (1924) showed that if a muscle is allowed to shorten and do work the total energy at its disposal is greater than when it contracts isometrically, i.e. without doing work. But to determine whether this sort of thing occurs in the case of maintenance we would want to know what the maintenance requirements are or at least how they would vary with changing conditions (temperature, etc.).

We have regarded maintenance as the processes opposing the death of the cell. The unfertilized egg, as we know, dies within a limited time after being shed. A study of the life span and respiration of unfertilized eggs under various conditions might then be expected to yield further information concerning these processes. Recent work on this subject (Whitaker, 1937; Schechter, 1937; Tyler, Ricci and Horowitz, 1938) shows that the life span may be prolonged in various ways without necessarily altering the respiration. But this work does not as yet add very much to our knowledge of maintenance.

VI. THE RISE IN RESPIRATORY RATE DURING DEVELOPMENT

We have regarded the developmental changes as dependent on the respiration, the rate of oxygen consumption being taken as a measure of the energy available for the various processes. We may consider now the possibility that the developmental changes determine in turn the rate of respiration.

It has been known, since the measurements of Warburg (1908) on sea-urchin eggs, that the rate of respiration rises during development. The increase in rate is not directly proportional to the increase in number of cells (cf. Needham, 1931). It might, nevertheless, depend upon changes brought about by cell division. To examine this question we would want to block or retard cleavage by some agent that does not alter the initial respiration. That is, we must exclude a direct effect of the agent employed on the rate of respiration. Then if the rise is subsequently affected it may be related to the failure of the cleavage processes. These conditions have been met in some recent experiments by Brachet (1938) and Tyler and Horowitz (1938).

Brachet found that if eggs of the annelid, *Chaetopterus*, are activated with KCl the initial respiration is the same as that of the fertilized eggs but the increase in rate occurs much more slowly. The eggs activated with KCl undergo what has been called "differentiation without cleavage" (Lillie, 1902). Actually, mitotic processes do occur in these eggs. Pasteels (1934) and Brachet (1937) have shown that the eggs after extruding polar bodies undergo a series of monaster cycles during which there is an increase in number of chromosomes and lobulations simulating cleavage. But the furrows disappear. The various changes and the attainment of the ciliated trochophore-like stage proceeds much more slowly than in the case of the fertilized egg. Also thymonucleic acid synthesis, which may be taken as a chemical index of mitotic activity, is greatly retarded in the treated eggs. The retarded rise in rate of respiration roughly parallels the retardation in the developmental changes.

Tyler and Horowitz obtained quite similar results with eggs of the gephyrean worm, *Urechis*. The non-cleaving eggs were produced in this case by means of a short treatment with dilute ammonia. Here again the initial respiration is the same as that of the fertilized eggs but the rise is greatly retarded (see Figs. 4, A, A′, B, B′). In addition measurements were also made on cleaving eggs produced by means of a somewhat longer treatment with ammonia. In this case the rise in respiratory rate (Figs. 4, C, C′) is more rapid than with the non-cleaving eggs, but it is still considerably slower than with the fertilized eggs. Cleavage in these eggs is correspondingly slower than in the fertilized eggs. Measurements were also made on fertilized eggs in which cleavage is inhibited by means of phenylurethane (Figs. 4, D). With the proper concentration of phenylurethane cytoplasmic division may be inhibited without any immediate effect on the respiratory rate. Nuclear division continues but at a retarded rate. Again the rise in respiratory rate is retarded.

If it were possible to block completely the mitotic

activity without altering the initial respiration one would expect complete failure of the rise to occur. But that is a rather ideal situation which is evidently not easily attained. The present results, however, furnish strong evidence that changes brought about in the egg by its developmental activity determine the rate of respiration. On the assumption that mitosis is an index of growth in this type of egg we might regard the rise in respiration as a function of growth.

Earlier than the above-mentioned experiments Lindahl (1936, 1938) has shown that Lithium inhibits the rise in rate of respiration of the sea-urchin egg while the initial rate is unaffected. This is of particular interest because of the rather specific morphological effects of Lithium (exogastrulation, etc.) and Lindahl attempts to relate the retardation of the rise to the "endodermalising" effect produced. It may be noted, however, that Lithium has a decided retarding influence on development, as MacArthur (1924) and others have shown. But no information is given by Lindahl as to the rate of cleavage, etc. of the treated eggs.

A careful study has been made recently by Horowitz (1940a) of the rise in respiratory rate and the respiratory quotient of developing eggs of Urechis. His findings extend to this type of egg Needham's view of a succession of energy sources in ontogeny, resulting from factors operating within the developing tissues and not alterable by the addition of one substrate during the period of combustion of another. In sea-urchin eggs he (1940b) has further examined the respiratory rise by artificially producing *Dauerblastulae* through the action of thiocyanate. The respiratory rate of the *Dauerblastulae* does not rise above the level characteristic of the normal blastula. Here again the initial respiration is unaffected by the treatment and the failure of the rate to rise above the blastula level is evidently the result of the inhibition of development that occurs at that stage in the thiocyanate-treated eggs.

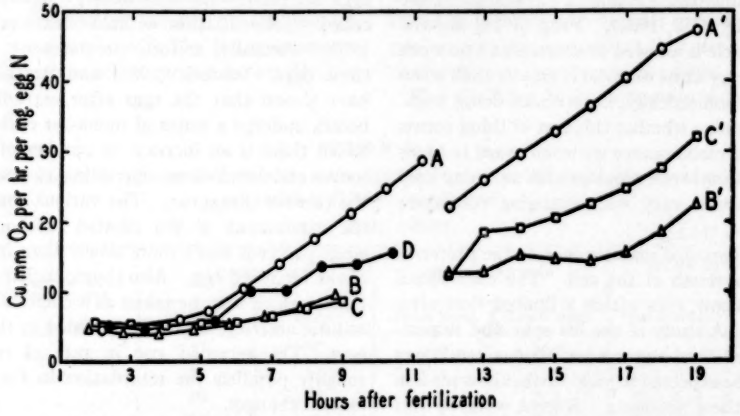

FIG. 4. RATE OF OXYGEN CONSUMPTION OF URECHIS EGGS AT 22°C.

Curves A and A′, normal fertilized eggs; B and B′, non-cleaving artificially activated eggs; C and C′, cleaving artificially activated eggs; D, phenylurethane-treated eggs. A′, B′ and C′ are not direct continuations of A, B and C since the eggs had been cultured at a lower temperature (18°C) for 11 hours previous to the measurements. (After Tyler and Horowitz, 1938.)

VII. OXYGEN DEBT

One of the reasons for considering the rate of oxygen consumption as an index of the energy supplied is that development stops under anaerobic conditions. There is, however, evidence that the cessation of development does not occur immediately upon the attainment of complete absence of oxygen (cf. Needham, 1931). This limited development under anaerobic conditions would be a serious objection to the view that oxygen consumption is a measure of the energy supply, unless it can be shown that the egg builds up a debt for oxygen equivalent to the amount of development it undergoes.

This question has been investigated by Brachet (1934) on eggs of the frog, and he finds convincing evidence of the existence of an oxygen debt. Developing eggs that have been subjected to anaero-

biosis show upon return to air a much higher rate of oxygen consumption than the controls. After a short time the rate drops to the control value, indicating that the debt has been paid off. Brachet also notes that with identical periods of anaerobiosis the intensity of the debt does not increase in the course of development, although as we know the rate of respiration rises. This is of interest in connection with the fact that greater developmental progress is made when eggs are subjected to anaerobiosis in earlier stages than in later stages of development. While Brachet has not shown that the total oxygen consumed to reach a given stage in development is unaltered by the introduction of a period of anaerobiosis, his results make that extremely likely.

Whether the debt corresponds to the oxidation of metabolites accumulated during anaerobiosis or to the reconstitution of an oxidising reserve was examined by determining the respiratory quotient after anaerobiosis. In the latter case (which is essentially an oxygenation without CO_2 production) the R.Q. should be abnormally low, and that is what is actually found.

VIII. CAN DEVELOPMENT BE ACCELERATED?

A question that often occurs to embryologists is whether it is possible to speed up the rate of development above that at the highest temperatures that an egg will stand. It is, of course, well known that the time of metamorphosis of amphibian tadpoles can be advanced by the administration of thyroxin and other agents. But we do not regard this as an acceleration of development. The work of Rowntree (1936, 1937) and his collaborators on the effect of injecting thymus extract in rats through succeeding generations are perhaps more to the point. But the results do not appear to be as yet generally accepted.

An acceleration of development following inhibition has been reported recently by Buchanan (1938, 1940) in salamander embryos. If the embryos are subjected to a low temperature (6°C) for short periods (up to 6 days), it is found that on subsequent development at the control temperature (21°C) they practically overtake the controls by the time that stage is reached at which the balancers are lost. Acceleration is noted in earlier stages too. Buchanan's methods have been criticized by Ryan (1941a) who in turn, however, presents statistical evidence that the rate of cleavage and of later development in *Rana pipiens* is accelerated by an exposure to low temperature. He also reports an acclimatization after the increase in rate so that eventually the rate becomes that which is normal for the higher temperature.

Aside from these cases that have been mentioned there does not appear to be any evidence that development can be accelerated. There are several agents such as certain oxidation-reduction dyes (Barron, 1929; Runnström, 1930) and the substituted phenols (Clowes and Krahl, 1936, 1938) that are known to increase greatly the rate of respiration of developing eggs. But these agents rather than tending to accelerate development, either have no effect or inhibit it. There are a number of possible reasons why the acceleration of respiration should not necessarily result in a speeding up of development, even if we grant that the energy for development comes ultimately from the respiration. The stimulation by these agents might involve a short circuiting of the energy supplying mechanism. Or there may be concomitant injurious effects on the eggs. This seems to be particularly the case with the oxidation reduction dyes that have been employed, the concentrations giving a stimulation of respiration having a toxic action on the eggs. With the substituted phenols, however, no injurious effect is produced.

Another possibility appears in the results of Runnström's interesting experiments with respiratory stimulants. Runnström (1935) shows that pyocyanine stimulates only part of the respiration of the fertilized sea-urchin egg. The part of the respiration stimulated by pyocyanine is not inhibited by HCN and appears thus to be similar to the respiration of the unfertilized egg. Also, according to Lindahl and Öhman (1938) the amount of stimulation with pyocyanine decreases as the respiration rises (i.e. as development proceeds). It would seem then that this type of agent acts on a part of the respiration not directly concerned with the developmental changes.

The exact reason for the failure of these agents to work may very well be different in each case. It would, nevertheless, be of interest to determine the reason in order to learn what kind of treatment might be expected to accelerate development as well as to learn something of the nature of embryonic respiration. Possibly a substance less foreign to the egg should be employed. It has in fact been reported that echinochrome, which is obtained from the eggs, the blood and the test of sea-urchins, gives a 16-fold rise in the respiratory rate of the

unfertilized sea-urchin egg (Friedheim, 1933). This is far greater than has been obtained with any other agent ever employed. However, attempts (Tyler, 1939) to repeat these results have been unsuccessful.

While a stimulation of respiration need not result in a speeding up of development, a lowering by inhibiting agents should give a corresponding retardation in developmental rate provided that any oxygen debt that may be incurred is taken into account. There are a number of agents that are known to inhibit the respiration in a more or less reversible manner (e.g. cyanide, carbon monoxide, etc.). They also retard development. But whether the effect on development corresponds exactly to the effect on the respiration has never been determined. One reason is evidently that development cannot be slowed up very much with the chemical agents so far employed without injurious effects. More suitable agents are apparently required.

Considerable progress has been made in recent years in the elucidation of the mechanism of cellular respiration and fermentation. Ferments, active groups and protein carriers have been isolated as pure substances by Warburg and his collaborators, Theorell, Euler and others (see reviews by Warburg, 1937; Michaelis and Smythe, 1938; Northrop and Herriott, 1938). With these substances respiration and fermentation systems can be set up *in vitro* in which carbohydrate is broken down in quite specific ways. The cell structure is unessential for the reactions to proceed, since they go on in aqueous solution. But it is evidently essential for the transfer of energy and the coordination of the metabolic processes. Runnström (1937) has recently reviewed the relatively little work that has been done on the relation between cell structure and metabolism. While there are no general conclusions yet to be drawn, it is from investigations in this field that we may hope to learn something of the mechanism of energy transfer and utilization. This would be of importance not only in determining how development may be accelerated, but in further analysis of the factors responsible for the developmental changes.

IX. SUMMARY

An attempt has been made in this review to define the various fundamental processes that are involved in development, and to evaluate the evidence concerning their dissociability as a preliminary to a discussion of the energy requirements of differentiation in particular. The evidence obtained from observations on developing embryos under naturally occurring, as well as experimentally produced, conditions is shown to afford justification for distinguishing between the processes of maintenance, growth and differentiation (and its components) in development. At the same time the close integration of these processes in normal development and the conditions under which they are inter-dependent are manifest in many of the experiments discussed.

A theoretical discussion is presented of the energy requirements in development and more especially for the processes of differentiation since it is that which characterizes the developing embryo. This is considered from the point of view of the chemical changes (synthesis) and mechanical changes (alterations of shape) that may be involved. The type of information needed and the difficulties involved in a direct demonstration and evaluation of the requirements are shown to point toward the desirability of an indirect method of attack. This is supplied by the application of the principle of similitude (dimensional analysis) to the results of experiments with dwarf embryos. The general applicability of this principle to other problems of biodynamics is indicated. In the case of embryonic differentiation the work shows the existence of a distinct energy requirement for the process, and the conclusion is shown to be substantiated in experiments with giant embryos and thick-walled embryos.

The action of temperature on rate of development and rate of respiration is discussed from the point of view of the developmental processes and energy requirement vs. production. It is shown that there is no optimum temperature at which development is accomplished with a minimum of respiration.

The normal rise in respiratory rate that occurs during development is shown to be dependent upon changes brought about by cell division. The existence of the ability, on the part of developing eggs, to build up a debt for oxygen is demonstrated and objections to the view that oxygen consumption is a measure of the energy supply are thereby removed. The possibility of accelerating development is examined particularly in relation to respiratory stimulants.

I wish to acknowledge my indebtedness to Professor T. H. Morgan who has read the manuscript and made many helpful suggestions.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that The Quarterly Review of Biology *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to B. H. Willier, Editor of* The Quarterly Review of Biology, *Department of Biology, Homewood Campus, The Johns Hopkins University, Baltimore, Maryland, U. S. A.*

NATI SUNT MURES, ET FACTA EST CONFUSIO

Being a review of *Voles, Mice and Lemmings: Problems in Population Dynamics*, by Charles Elton. (Oxford University Press, New York: Clarendon Press, Oxford, 1942. Pp. 496.) *By G. Evelyn Hutchinson, Yale University.*

The name of Elton has been associated with studies on populations of small mammals for nearly twenty years and it is therefore with eagerness that an ecologist takes up this monumental volume which, produced after two years of war, still maintains in its material aspects the distinction to be expected of its publishers. Here, hidden in close to five hundred pages of text, must lie the secret of the lemmings and in this great work we may hope to find exposed the working of that strange metronome that seems to regulate the animate beings of arctic lands. A first reading, however, leaves a sense of disappointment; in spite of the continuous activity of Elton and his associates, he can only "begin to see vole populations in dynamic terms: with numbers, rates of increase, life-curves, and movements interwoven into a pattern that ten or twenty years' further work may enable us to understand completely." All this immense labor is then preliminary, is the reconstruction of the historic background, the elaboration of technique. The main investigation has yet to come. Meanwhile, every student of animal population will be grateful for these studies, which provide the most comprehensive existing body of data on the periodic fluctuations of any group of animals.

The book is divided into four parts. The first is a review of previous work on murid populations, in Central Europe, the Soviets, North America, and certain other parts of the world. The effects of biological control, in France particularly, are considered; the summary of the Russian investigations is most illuminating; Hamilton's studies are naturally regarded the most significant contributions from the United States. The second part is devoted to Britain and Scandinavia, and deals with the work of Elton's own Bureau of Animal Populations at Oxford and with the Norwegian lemming. The whole of the rest of the book is devoted to an immensely detailed account of the periodicities found in northeastern arctic Canada, Part 3 being limited to northern Labrador, Part 4 to Ungava. No detail that might be relevant seems to be omitted; everything cognate to the subject is here, the shiny leaves of the mountain laurel, the starving Indian, the apt quotation from Bridges. Yet on page 482, after a discussion of epidemic diseases in sledge-dogs, the work suddenly ends with an allegory of nine lines. A few more facts are added in an appendix and the volume completed with a somewhat unsatisfactory index. The final section, the integration of the material that might have been expected, is nowhere to be found; the war may have prevented a concluding section from being written, but the whole tenor of the work suggests that Elton prefers each reader to construct mentally such a chapter for himself. This is a difficult task, particularly for the reviewer, who must think publicly. Like some aboriginal woodman who has learned to know intuitively the whole puzzling geography of an immense forest, Elton finds his way easily through thick undergrowth of detail, without any intellectual map to guide him. The less practiced reader must digress to set the problems somewhat more abstractly than his guide is willing to do.

The fundamental question can be expressed simply enough. In many parts of the world small rodents multiply, becoming excessively numerous, and often very destructive, in certain years, after which the population suddenly declines. These increases may appear sporadically, but usually there is a clear indication of periodicity in any given locality, and in almost every region where the matter has been studied, the interval between maxima tends to be three to four years. The problem we must set ourselves is to ascertain the causes of this periodic increase and decline.

In constructing an intellectual map as a guide to the possible solutions of the problem we may first notice

that, if the numbers of any animal depend on the reproductive potential of the population of the preceding generation and on the environmental resistance, and if the reproductive potential of the individual is considered constant while the environmental resistance fluctuates with the meteorological conditions, we shall have a fluctuating population. Any given departure from the mean meteorological conditions will have, in any locality, a definite probability of occurrence, and if no secular changes are occurring in the climate, the departure in one year is independent of the departure in any other. As we suppose that both climate and number of parents available determine the population, the occasional chance appearance of "runs" of favorable or unfavorable meteorological conditions will permit the building up of large populations, or cause progressive declines. Over a long period of time the mean interval between such maxima or minima will tend to the same value as the mean between maxima or minima observed over another long period, or in another locality, where the frequency distribution of meteorological probabilities is the same. This principle we shall call *statistical quasiperiodicity*. It introduces a note of caution into all work on animal numbers; many of the less regular periodicities, such as the so-called 5–7 year cycle in partridge and grouse in Great Britain, may be of such a kind. Elton's data on the voles clearly represent something more regular than this.

If we have a real periodicity, it may presumably be due to cyclical events outside the ecosystem or to the generation of cycles by mechanisms inside the biological system, the former condition corresponding to forced vibrations in mechanics, the latter to free vibrations. In the case of two isolated but climatically and geographically close populations of an animal, if the periodicity is externally determined or forced, the fluctuations in the two populations may reasonably be expected to be synchronous. In more remote regions, the oscillations might show a constant phase difference, but any irregularities in one region should correspond to irregularities in another. If the oscillation is free, there is no reason why the two populations should fluctuate in phase or with correspondence in their irregularities. The exact number of possible ways in which free fluctuations may occur is hard to ascertain *a priori*, but most cases probably reduce formally either to the symmetrical, so-called *classical oscillations* involved in the *prey-predator* relationship (Lotka-Volterra periodicity, developed in a different form by Nicholson and Bailey) or to the *relaxation oscillations* of Gause. Gause's theory involves the building up of the population to a certain critical level, after which it becomes unstable and declines suddenly, the most obvious causes of the decline being exhaustion of food, or abnormal opportunities for the spread of epidemics, when the critical density is reached. A final word of warning is needed; it is tempting to suppose a multiple causality, and this is no doubt correct, but it is clear that one must not postulate interaction of periodic causes with different periods, not multiples of each other, and then hope to obtain a highly regular set of maxima. This has been done in the past by authorities who should have known better.

The facts that Elton and his predecessors appear to have determined are these:

(a) Over large tracts of land the periodicities often appear to be synchronous; this is the case over northern Labrador and Ungava. But when northern Labrador and Norway are considered, Elton, who formerly believed synchronism to exist, now merely states that he had hoped to make a comparison; although no such comparison apparently is made in the text, it is easy to see that there is no evidence for an identity in phase. This, however, does not exclude synchronism altogether, because the best data for comparison relate to a derived element, the number of foxes killed, and the maxima in foxes may either *coincide with* or follow by *one year*, the maxima in lemmings and voles. Casual examination, without detailed statistical analysis, suggests to the reviewer that it is actually very unlikely that the maxima of the primary population of rodents are in phase in the New and Old Worlds. Further analysis of the distribution in the two series of abnormally long or short periods (3 or 5 years) might, however, be made. In spite of the huge distances involved in Labrador and Ungava it is uncertain that a synchronism significant in separating internal from external causation, can be established on a continuous land mass. In Great Britain, and in Bavaria, moreover, cycles are known in different *Microtus* populations, all fairly regular, but not in phase.

(b) The periodic appearance of Microtinae as major influents in any eco-system, naturally alters all the trophic dynamics of that system. In Norway and the Canadian arctic there is a shift in food habits of predators whenever the maxima occur, releasing the pressure on other species. Any argument based on co-occurrence of cycles in non-predatory animals in the same region may therefore be as irrelevant to the problem of internal versus external control, as is the increase in foxes when the lemmings increase. It must also be observed that the predatory carnivores, known so well from the statistics of the fur trade, are not involved in generating a Lotka-Volterra cycle with the rodents, for the latter fluctuate after man has decimated the population of carnivorous mammals. Moreover it may be noted, though it has apparently not been pointed out in print, that if the expression for the approximate period, given by Volterra, be used in the case of the snowshoe rabbit and its principle predator, we obtain an absurd expectation of life for a starving lynx.

(c) Although the curves indicating the numbers of predators killed (or in other cases, the actual numbers of cyclical rodents, such as *Lepus americanus*), show, when based on data derived from large areas, reasonably symmetrical maxima and minima, this symmetry is

probably largely due to the superposition of a number of asymmetrical curves, some being slightly out of phase. Everyone who has studied the matter carefully concludes that at a given station the decline in the primary fluctuating population is rapid and asymmetrical. Moreover, the animals with a 3–4 year cycle are apparently all annuals, and there is a critical period each spring when the whole breeding population consists of middle-aged individuals with a relatively low expectation of life, as Leslie and Ranson, of the Oxford Bureau of Animal Population, have shown. The existence of this critical period, should any postponement of suitable breeding conditions occur, may be disastrous, and is therefore one of the most important properties of the life history of voles. Of itself, however, the critical period does not explain periodicity.

(d) Though analysis of field records suggests a picture not unlike Gause's relaxation oscillation, no clear evidence of epidemic disease as the controlling factor exists. In some declines in Britain, the Oxford workers found Toxoplasma infections more or less epidemic; in other cases the most careful pathological study failed to reveal any general morbidity in the population. A form of tuberculosis is occasionally reported, and though its incidence is of great pathological interest, there is no evidence that this disease plays any part in the regulation of cycles. Certain interesting facts relating to the age distribution of infection by annual parasites also came to light in the Oxford studies, but do not bear on the main problem.

(e) Hamilton's work suggests a great rise in fertility as the numbers increase. This is in part due to sexual undercrowding or reduction of encounters between the sexes, at the minimum, but at that time the breeding season is shorter, and the number of young per litter lower, than in the later parts of the period of recovery. Unless the reduction in fertility actually intervenes in a still more extreme form, immediately prior to the decline, we cannot interpret cyclic changes in population in terms of cyclic change in reproductive potential, for, at the minimum, the population has ceased to decrease and is about to increase. Elton summarizes some evidence that overcrowding causes an excessive incidence of combats, both between males and between females; this may induce an increased mortality and conceivably might result in low fertility and so, in view of the critical period in the spring, cause a decline. Such social antagonisms can hardly be the explanation of the low litter number, per fertile mating, at the minimum. Hamilton thinks that such variation in fertility is a phenomenon general in small rodents; the limited investigations of Elton's associates seem to indicate that in *Microtus agrestis* there is less reproductive variability than in the American forms. The problem of fertility is clearly of the greatest importance, and its solution might throw light on some of the obscurer aspects of human reproduction.

(f) Something can be learned from comparisons with other cyclic animals; this, however, is hardly attempted by Elton in the present volume. Though the trophic control of the ecosystem by a four-year microtine cycle is most marked in the northern Tundra, there is no reason to suppose that the ten year cycle of the Canadian forest zone, based on the fluctuation of the numbers of the snowshoe rabbit, is a latitudinal matter, as the four year cycle appears again in *Microtus* far to the south, in New York. The basis for the difference must lie in the sizes, or more directly, in the lengths of life span, of the major primary consumer (herbivore) in the food chain. This hypothesis is strengthened by the fact that squirrels seem to occupy an intermediate category, with a 5–7 year cycle.

These six generalizations seem to point towards an internal relaxation oscillation of Gause's kind, though the cause of the relaxation is still obscure. In one place Elton suggests that the reaction of the animals on the vegetation may almost approach the classical prey-predator interaction of Volterra, though here the most probable result is likely to be a highly asymmetrical relaxation, as Gause has shown to occur in most cases of natural predation. Yet faced with the extraordinary similarity, if not simultaneity, of the cycles in populations spread over a great part of the northern hemisphere, we find it hard to avoid returning, as indeed Elton does, to some external climatic control. The particular meteorological results that are evoked in the present work are derived by Goldie from a study of the distribution of mean annual pressures over western Europe. Indications of an irregular cycle of about 3.8 years are found in such data. It must, however, be admitted that Goldie's period is but one member, and apparently not a very respectable member, of a great family of meteorological periodicities and quasiperiodicities. By far the most remarkable biological periodicities known are derived from the studies of Douglass and his associates on tree growth; here there is no possibility of the cycle being free. Moreover, since there is fairly good evidence that the growth of comparable Miocene trees and other ancient annual phenomena of variable intensity, behaved essentially like modern trees in the frequency of appearance of any given cycle, it appears that the cycles, though they come and go irregularly, have definite probabilities of occurrence, and are therefore *real*, and, being independent of the present detailed distribution of land and water, are presumably *solar*. Different groups of trees show certain cycles more intensely than other groups, so that we may regard the system "tree + climatic environment" at any place as resonating to certain periods in the extremely complex meteorological rhythmicity of the whole atmosphere. If animal populations behave in the same way, the length of the life cycle may perhaps determine the period of resonance. But this is a flight into theory further than our author would permit us; let us therefore wish him a speedy return to his inter-

rupted studies, so that, after many mice have been born, we may, in ten or twenty years, have a companion volume in which the confusion that now permeates the whole subject will be resolved into order.

BRIEF NOTICES

EVOLUTION

THE EXTREMITY BONES OF SINANTHROPUS PEKINENSIS. *Palaeontologia Sinica, New Series D, No. 5; Whole Series No. 116.*

By Franz Weidenreich. Geological Survey of China, Peking. 11¼ x 8⅝; 150 + 34 plates. 1941 (paper).

Our knowledge of early man has been greatly advanced by the important discovery of the remains of *Sinanthropus* near Peking. These significant finds have been described in a series of exemplary monographs by the late Davidson Black and more recently by Professor Weidenreich. The previous reports were devoted chiefly to skulls and teeth which, curiously enough, had been preserved in larger numbers than other skeletal parts. The present contribution deals with the few extremity bones of *Sinanthropus* found so far. These comprise seven incomplete thigh bones, two fragments of upper arm bones, one incomplete collar bone, and one wrist bone (lunatum). All these specimens are from adult individuals and, with only one exception, from males according to the most probable sex determination. Unfortunately all the long bones lack their joints, only more or less extensive portions of the shafts having been preserved. Practically no doubt is left that these limb bones really belong to the same type of early man as the previously recorded skulls and teeth. These scanty, yet most welcome and encouraging finds appertaining to the limbs of *Sinanthropus* are described in very careful and adequate detail. Humerus, femur and clavicle have been reconstructed so that at least their total lengths can be estimated with a fair degree of confidence. They are compared meticulously with the corresponding bones of other fossil men, of modern man and of the man-like apes in regard to their main proportions and their most significant descriptive characters.

Of the conclusions the following are specially noteworthy: In all their main features these extremity bones are practically identical with those of modern man and show none of the conditions characteristic of the apes. This is highly interesting and quite surprising in view of the many primitive or at least peculiar conditions found in the skulls. As a distinctive trait of *Sinanthropus* is mentioned that in the femur and the humerus the medullary canal is strikingly narrow and the walls of the shafts are correspondingly thick. Weidenreich considers it safe to conclude that *Sinanthropus* had already assumed a completely upright posture. He estimates the stature of this fossil man at approximately 156 cm. in the male and 144 cm. in the female.

In an appendix the author discusses the precise nature and the probable causes of "the fragmentariness of the extremity bones." Here it is concluded that apparently "carnivores and man competed in the breaking of bones both human and animal." In his introduction Weidenreich sides in principle with that steadily growing number of scientists who are dissatisfied with the present, often misleading and certainly inconsistent, nomenclature applied to the various forms of man. Even though we have undoubtedly been far too generous in bestowing so many different generic names to our nearest fossil relations, it is startling to read the author's confession: "I believe . . . that all known hominids belong to one-and-the-same species." Let us hope that the fashions in the taxonomy of the Hominidae will not swing from one extreme to the opposite!

A MIOCENE SEA LION FROM LOMITA, CALIFORNIA. *University of California Publications in Zoology, Volume 47, No. 2.*

By Gretchen M. Lyon. University of California Press, Berkeley and Los Angeles. 10¼ x 6¼; 30 + 6 plates; 1941 (paper).

GENETICS

AMERICAN DAIRY CATTLE: *Their Past and Future.*

By E. Parmalee Prentice. With Chapters on Dairy Cattle in America by Ernest L. Anthony, Lloyd Burlingham, Clifford Clevenger, and Others. Harper and Brothers, New York and London. $3.00. 9¼ x 6⅛; xix + 453; 1942.

This excellent and colorful volume presents in a clear and authoritative manner the history of the development of our Holstein, Jersey, Shorthorn, Guernsey, Ayrshire, and Brown Swiss breeds of American dairy cattle. In addition to the time-worn histories and encyclopedias usually used for research, the author of this work has availed himself of another very valuable source of data relating to the history of cattle; namely, the Port and Custom House records of Britain, and the contemporary advertisements in *The Times*. The result is a fascinating history of one of the most intriguing facets of man's progress.

The history of cattle is really the history of man, inasmuch as they have shared his struggle for existence and at the same time have contributed materially to his welfare. Although cattle were tended and were used for their meat and dairy products from the earliest days of recorded history, their purposeful breeding had

its origin in England during the 17th Century. There, under the impetus of three factors (the need for more food for man, the importation of Dutch cattle, and the increase in supply of agricultural products which could be used for cattle food) the random crossing of native stocks began. Animals which were fed and bred into greatness became a breed. Of course there was no knowledge at that time of the laws of inheritance, so that acquired characters, maternal impressions, and many other outside influences were thought to affect the character of the offspring. Thus, importance was soon attached to cattle from a certain locality, or to those being bred by a particular man who was able to keep his stock well fed. This was essentially the picture of cattle production up to the beginning of the present century, when, in America, under the impetus of increased knowledge of heredity and the institution of the dairy breed herd book, the all-important factor became the lineage of the stock—lineage without reference to production qualities. In the past decade, with the collection of detailed production records and the application of statistical methods, the progeny test (which takes into account the productive ability of the progeny, and which holds that this is even more important than lineage) has been established and is accepted as the last word in method of live stock improvement. From the recent production records of cattle selected by the progeny test method, no one can even hazard a prediction as to how far the development and improvement of dairy cattle can, and will, go.

For anyone interested in live stock production and improvement, this history of cattle will prove as fascinating as it is informative. The text is profusely illustrated and is supplied with a detailed index.

METHODS OF PLANT BREEDING.

By Herbert Kendall Hayes and Forrest Rhinehart Immer. McGraw-Hill Book Company, New York and London. $4.00. 9 x 6; xii + 432; 1942.

This new book is an excellent addition to the literature at the disposal of students of agriculture and plant breeding who are familiar with the elements of genetics. It is predominantly concerned with problems of practical breeding. However, the importance of genetic and cytogenetic principles is emphasized throughout the book.

The greatest part of the book is devoted to the description and critical evaluation, from both the theoretical and practical standpoints, of the general principles and methods of modern plant breeding. A brief discussion of the genetic and cytogenetic basis of plant breeding is followed by chapters concerned with the mode of reproduction in relation to breeding methods, technics of selfing and crossing, the pure line method of breeding naturally self-pollinated plants, the backcross method, hybridization as a method of improving self-pollinated plants. These are supplemented by special chapters concerned with the breeding of some economically important plants: wheat, oats, barley, flax and corn; with controlled pollination methods of breeding cross-pollinated plants and seed production; and by a thorough discussion of statistical methods used in plant breeding.

The text is accompanied by 20 pages of bibliography, a glossary and statistical tables.

NEW PATHS IN GENETICS.

By J. B. S. Haldane. Harper and Brothers, New York and London. $2.50. 8¼ x 5⅓; 206; 1942.

In introducing this new book to the non-professional reader, the author shows that the present day geneticist "must be a jack of all trades and it is to be feared that he may become the master of none" (p. 15). That the latter is not a necessary corollary of the former is exemplified by the author himself who, in a series of lectures delivered at the University of Gröningen and now published in bookform, not only treats with great competence the various aspects of genetics, but also amply quotes his own contributions in the diverse fields of this science.

The first chapter (The science of genetics) is devoted to a general review of the field of genetics. The relations of genetics to biochemistry and embryology are discussed in the next two chapters (Genetics and biochemistry, Genetics and development), while the last two chapters (The genetics of some human abnormalities, The formal genetics of man) are specially concerned with human genetics.

The book, written in a clear but not wholly unpretentious style, will be read with equal interest by students of genetics, embryology, biochemistry and medicine.

SEVEN PAPERS IN GENETICS AND PHYSIOLOGICAL GENETICS OF DROSOPHILA MELANOGASTER. *University of California Publications in Zoology, Volume 49, Nos. 1–7*

By Richard Blanc, Werner Braun, Eldon J. Gardner, Richard Goldschmidt, Claude A. Villee, Jr. University of California Press, Berkeley. $2.00. 10¼ x 6⅔; 184 + 11 plates; 1942 (paper).

This volume, under the general title *Seven papers in Genetics and Physiological Genetics of Drosophila melanogaster*, contains the following articles: Observations on the production of wing scalloping in *Drosophila melanogaster*, by Richard Blanc; Phenocopies and X radiation in *Drosophila melanogaster*, by Richard Blanc and Werner Braun; The effect of X-radiation upon bristle pattern in *Drosophila melanogaster*, by Richard Blanc and Claude A. Villee, Jr.; The effect of changes in time development on the phenotype of mutants of *Drosophila*

melanogaster, by Werner Braun; A further study of genetic modification of dominance, especially by position effects, by Eldon J. Gardner; A further contribution to the analysis of scalloped wings in *Drosophila melanogaster*, by Richard Goldschmidt and Eldon J. Gardner; A study of hereditary homoeosis: the mutant tetraltera in *Drosophila melanogaster*, by Claude A. Villee, Jr.

A REPORT ON EXPERIMENTS WITH COLCHICINE *by Laymen Scientists during 1941. A Co-operative Research Project.*

By O. J. Eigsti and Barbara Tenney. University of Oklahoma Press, Norman, Oklahoma. 35 cents. 9 x 6; 32; 1942 (paper).

This pamphlet is a report of a project designed to encourage laymen to carry out experiments with colchicine (by its use polyploidy may be produced). Colchicine along with directions for an experiment with it were sent to a group of laymen who were then requested to turn in a report on their work. The present pamphlet describes the nature of the project, gives some facts about colchicine, gives the details of the carrying out of the project, analyzes the geographic distribution and occupations of the experimenters, and summarizes the results of the reports. Successful induction of changes was reported in 19.4 per cent of the completed experiments or in 7.1 per cent of the total number of experiments. Over 60 per cent of the experiments were not reported or incomplete. The authors conclude that the use of colchicine by laymen is not of great economic value but is a valuable method of education. From the fact that 51 per cent did not send in a report it would seem that it also shows how difficult it is to keep laymen interested in such a project.

BIOLOGICAL SYMPOSIA. *Volume VI. I. Temperature and Evolution. II. Isolating Mechanisms. III. Genetic Control of Embryonic Development.*

Edited by Th. Dobzhansky. The Jaques Cattell Press, Lancaster. $3.50. 9½ x 6½; xii + 355; 1942.

This sixth volume of the series of Biological Symposia contains papers read by fifteen authors at three different symposia. The subjects of these were: Temperature and evolution; Isolating mechanisms; Genetic control of embryonic development. In the first two the emphasis is on the evolutionary aspects of the problems, the third one is a further attempt to bridge the gap between embryology and genetics. Thus this volume is another manifestation of the continually growing interest of geneticists in correlating their particular field with general biological theory.

The volume is edited and prefaced by Th. Dobzhansky.

GENERAL BIOLOGY

UNIVERSITY OF COLORADO STUDIES. *Series D. Physical and Biological Sciences, Vol. I, No. 4.* Containing the following: *Vegetation of the San Luis Valley in Southern Colorado*, by Francis Ramaley; *Alphabetical Index to Volume 1 of Series D (Physical and Biological Sciences); Title Page and Contents.*

University of Colorado, Boulder, Colorado. $1.00. 10 x 6¼; 231–279; 1942 (paper).

HUMAN BIOLOGY

TIME AND THE PHYSICIAN. *The Autobiography of Lewellys F. Barker.*

By Lewellys F. Barker. G. P. Putnam's Sons, New York. $3.50. 9 x 6; ix + 350. 1942.

Due, perhaps, in greatest measure to the changes in mores which marked the decline of aristocracy and the rise of the proletariat, writers of autobiographies of late years have exercised a restraint in frankness, absent in the autobiographies of Cellini, Casanova, Rousseau, and Franklin, and in the letters and diaries of men and women of the 17th and 18th centuries, which revealed so vividly and so fully their real natures and portrayed the spirit of the times in which they lived, moved, and had their being. From such as these we get clear-cut pictures of the individual scribes, their associates, and their general milieux. In this natural frankness which flourished before the reign of Mrs. Grundy, the stepdaughter of the "puritan" sects and the godmother of the Comstocks, lies much of the charm these writers exert upon intelligent students of human nature. The same criticism applies, with certain notable exceptions, to biographers. Fortunately, in the novel, which deals in essence with the biographies of imaginary persons, authors have to a considerable degree escaped the fetters of a false prudery.

Beyond the members of the other learned professions, accounts of the accomplishments and descriptions of the personalities of successful medical men possess a wider popular interest. Doctor Barker is in eminent degree a successful medical man in scientific attainments, in teaching, in diagnosis, and in therapy. In addition, he is a man of unusual charm; his activities have covered many countries and climes; his interests are broad and deep; his ideals are high. By dint of hard labor, self-denial, and a peculiar perspicacity in the choice and direction of his studies, he so cultivated his natural gifts that he early attained eminence in several branches of his chosen calling. Barker's early training in chemistry, anatomy, physiology, general pathology, pathological anatomy, and bacteriology, and especially in neurology and psychology, gave him a unique background for the study, teaching, and practice of clinical medicine. His clinical lectures given in the amphitheatre, were prepared with the care and thoroughness

which characterized those of certain great clinical teachers of earlier generations of whom Da Costa of Philadelphia and Trousseau of Paris are pertinent examples.

In the study and care of private patients, occupying his later life, Barker has considered the individual as a whole; the man, himself, as an integrated organism. Penetrating beneath the subjective symptoms and the pathological processes disclosed by exhaustive investigation with the aid of methods and techniques of precision, he has sought to obtain that comprehensive insight into all the factors involved, which is so essential for accurate diagnosis and intelligent therapy.

The author's avowed intent is an honest attempt to dissect and to evaluate his own personality as influenced by heredity and environment, personal and physical. The result is a book well written and readable withal; but in the opinion of this reviewer, undue space is given to narrative of travel and to hero worship of teachers and colleagues, the more important of whom have been already exhaustively written about.

Despite his keen and penetrating mind, and his wide reading, influenced unduly perhaps by his early associations, Barker confesses allegiance to the current Christian (*sic*) mores, to belief in a very broad type of democracy, and to adherence to the "uplift."

To the next candidate to autobiography, this reviewer recommends perusal of those of Franklin and Marion Sims.

The clear-cut photograph used as frontispiece, reveals to the amateur physiognomist much of the author's character, especially his earnest determination and the charm that has endeared him to so many in all walks of life.

THE BIOLOGY OF THE NEGRO.

By Julian H. Lewis. University of Chicago Press, Chicago. $5.00. 9 x 6; xvii + 433; 1942.

The author, who is Associate Professor of Pathology at the University of Chicago, has undertaken the arduous and much needed task of collecting and reviewing a very large part of the most significant and heretofore widely scattered literature appertaining to Negro biology. The resulting volume will be highly welcomed by medical men, anthropologists and sociologists, but it must be judged as a pioneering effort hampered by several basic difficulties. The latter are connected with the precise definition and proper limitation of the subject and fall chiefly under three headings: (1) Does the term "Negro" represent a biological entity? (2) What share of the "Negro" peculiarities discussed is due to real and hereditary qualities and what share is caused chiefly by environmental factors of an economic or sociological nature? (3) Can any one scientist to-day be equally well at home in the many branches of biology so that a work of this sort does equal justice to the many different subjects dealt with? Regarding the term "Negro" the author states in his preface:

> In this book the American usage is followed in review of the American literature, and for other literature only that is used pertaining to the Negroid people of the east and west coasts of Africa and of central and southern Africa as well as the intermixtures called 'colored' by the English. It is confessed that this word 'race' is used very loosely . . . .

It is evident that the collected information does not appertain to pure stock, but must frequently refer to variously mixed groups and this even in the case of reports from Africa. Regarding the above second question it can here be merely mentioned that for a great many of the diseases discussed it has to be left undecided to what extent nature or nurture is responsible for apparent racial peculiarities. The table of contents supplies a partial answer to the third question raised. There are chapters on Population and vital statistics (17 pages), on Anatomy (64 pages), and on Biochemical and physiological characteristics (17 pages); the remaining 308 pages of text are devoted to a discussion of different diseases, i.e. to what the author proposes to call "anthropathology" (in the reviewer's opinion an inadmissable term). It is readily seen that the normal conditions are not nearly as well represented as are the morbid ones. This discrepancy is based to some extent and quite naturally upon the fact that the author's chief interest and experience lies in racial pathology and that hence this subject is discussed much more fully than the other fields of biology (psychology is not even mentioned). It must also be recalled, however, that there exists a real and marked difference between the total amounts of available information appertaining to normal race characters on the one hand and to racial peculiarities of disease processes on the other hand and this unquestionably for the reason that the number of people working in medicine is several thousand times greater than the total of investigators in all the different fields of normal human biology.

As a volume which reviews for the first time the enormous accumulation of data bearing upon the characteristics in the Negro's reactions to disease this book belongs in every medical library. Of the positive findings few permit, as yet, broad generalizations. Among the latter the following may here be quoted: "Surgeons who have had considerable clinical experience with Negroes commend them as excellent surgical risks. They are stoic in their reaction to pain and discomfiture, do not easily go into shock, take anesthesia well, resist infection, and show remarkable powers of recovery."

The usefulness of this volume is enhanced by the very adequate subject index and by the author index.

SUN CHIEF: *The Autobiography of a Hopi Indian. Edited by Leo W. Simmons. Yale University Press,*

New Haven; Oxford University Press, London. $4.25. 9 x 6; x + 460; 1942.

Those who have idealized the Amerind are due for a rude shock when they read this book. It is not so much the autobiography of a moral degenerate as of a member of a community of moral degenerates. The Hopi Indians are a disappearing tribe and they know it, and are so animated by a philosophy of despair that they have given themselves over wholesale to a life of licentious excesses in which the entire population participates and in which the individual takes pride.

The delinquency of the Indian is popularly attributed to contact with white civilization. In some instances such a conclusion may be justified, for the conduct of the white man in most instances has been far from impeccable. But here we have one who, although exposed to civilization, never caught it, who repudiated a Christianity that he never understood in favor of the superstitious metaphysics of his ancestors, who spent his life in a community where no white person was welcome except the prostitute, yet whose entire career was devoted to pornographic practices, the product of an education that began in the cradle under the expert tutelage of all his female relatives, both natural and ceremonial.

The book was undertaken as a contribution to anthropology. Certainly it contains much that is of anthropological significance. The detailed account of the circumstances of the author's birth indicate how deeply the story was impressed on his consciousness by constant reiteration, and the practices of the medicine men on this as well as on subsequent occasions testify as to the power exercised by these people over their superstitious followers. The stories of his initiation into two secret societies throw light on the cultural heritage of his people, but the high spot in the book is the account of the famous snake dance, including the ritual which takes place within the kiva, of which the ordinary tourist is unaware. This ritual is supposed to be guarded, but it is partly revealed here to correct some misstatements in an earlier published work. One suspects also that a pecuniary compensation was not without influence in eliciting the information.

In the final analysis the greatest significance of this book will probably prove to be as an influence in the refutation of the impractical theory held by sentimentalists that all would be well with the Indian were the activities of missionaries and educators curtailed.

The reviewer's feeling on putting down this book is that the Hopi Indians have undergone considerable deterioration within rather recent years. It is difficult to reconcile the picture of the Hopi character which this narrator gives us with the tradition that makes the Pueblo Indians the most advanced in the Southwest, and the Hopi the noblest among the Pueblos. And the contrast between Sun Chief's picture of himself and the popular conception of some of the more dignified figures in Indian history, such as Logan, Osceola, or Elias Boudinot is very striking. But then there are many white men who do not measure up to the standard of Thomas Jefferson or Abraham Lincoln.

THE HOUSE IN THE RAIN FOREST.

By Charis Crockett. Houghton Mifflin Company, Boston. $3.00. 8¾ x 5¾; x + 300; 1942.

This is an informative anthropological book and at the same time, incredible as it may seem, a charming account of a long honeymoon among the little-known savages of Dutch New Guinea. The author has a degree in anthropology from Radcliffe and, since she really wanted to make good use of her training, she sailed with her husband in a 59-foot schooner through the Panama canal, among the South Sea islands, and to the western end of the land of the Papuans where they lived happily in their house on stilts in the rain forest. In the introduction Professor Hooton states that "the present work is a casual by-product of her contribution to science. Actually she measured nearly 900 greasy, smelly, filthy cannibals—a remarkable achievement for any tough, male physical anthropologist and a miracle for a fragile, blonde female."

Mrs. Crockett succeeded first of all in winning the confidence and even the affection of the really primitive natives among whom she lived. She has also succeeded in giving a delightful, intimate picture of the daily life and the child-like nature of her aboriginal neighbors with their simple ambitions, limited to food and love, their naive superstitions, and their enviably few needs and worries. These natives (*Madik*) were at first shy and timid as well as quite suspicious. Soon, however, Madik society trusted and accepted their white visitors, a change that was accelerated, as among most savages, by the readily offered medical aid of the Crocketts. The author admits cheerfully that they found it "far easier to become a successful quack than a competent doctor and we had more luck in treating magical diseases than physical ones."

The Dutch authorities have done their best to eradirate cannibalism at least in the coastal districts, but they have not yet changed the natives' views concerning this culinary subject. According to the author, the Madik "were profoundly shocked to hear that in our country a man may contemplate slaughtering and eating his own pig—it indicated a scandalous lack of delicacy and proper feeling. But to waste the nutritive value of a houseful of dead bodies would have seemed to them incomprehensively silly, wantonly spendthrift." Even though these and many other Papuan ideas and customs appear to be exceedingly primeval and savour decidedly of cavemen's days, these savages enjoy more happiness and find more occasion for laughter than most people with the so-called blessings of civilization.

YOUTH AND THE FUTURE: *General Report.*

By the American Youth Commission. American Council on Education, Washington, D. C. $2.50. xix + 296; 1942.

This is a report based on a survey of the conditions that affect the 22 million youth between 16 and 24 in the United States. Six years were spent by the committee in collecting and analyzing the data concerning all problems relating to the care and education of the nation's youth. The Introduction to *Youth and the Future* was written by Owen D. Young. In the preparation of the report "the major objective has been a philosophy which would be applicable both in war and in peace." We quote briefly some of their main findings:

The schools, forming the largest public agency for the training of youth, must revise many of their programs and undertake new ones. The promotion of literacy must continue to be principal among their functions.

Before such a level [a level where all children and youth, regardless of race, will receive at least a sound elementary school education] can be achieved for all youth in the nation, the Commission believes that the federal government must provide funds for the equalization of educational opportunity between the states since some are rich and some poor in resources.

Much of the present duplication and overlapping of authority and funds could be eliminated by a redistricting of the school service areas; . . . .

Provision of a sufficient number of schools for all youth will be unavailing unless the quality of instruction is immeasurably improved.

Financing of schools will not be enough; financing of the costs of education to the individual pupil must be undertaken in many cases, the Commission finds, as it states that all youth should be *enabled* to attend school up to the age of 16.

. . . during the immediate emergency period the Commission believes that rehabilitation camps should be established for youth turned down by the selection agents for the Army. It also proposes that a thorough physical examination be made available, free of charge, to every young American, immediately after his or her eighteenth birthday, . . .

In the future, health programs must also be instituted considerably before this "youth health year."

Because of the mounting number of youthful crimes [as many as one third of all persons arrested for offenses are under 25] the Commission believes with the American Law Institute that Youth Correction Authorities should be created in all states which will separate the youthful offenders from the older criminals during trials and while sentences are being served.

The Commission recommends creation of a public work youth agency within the Federal Security Agency where personnel can be in constant contact with the other social agencies whose programs impinge on the welfare of youth.

. . . by teaching youth how to use their leisure time wisely much of the mental illness which was found to be an accompaniment of unemployment can be eliminated.

PRACTICAL FINGERPRINTING.

By B. C. Bridges. With a Foreword by August Vollmer. Funk and Wagnalls Company, New York and London. $4.00. 7¾ x 5⅛; ix + 374; 1942.

Finger prints are an unforgeable signature, already established as indisputable legal evidence and a definite means of identification. The most complete up-to-date material on the subject is published in this practical handbook.

Beginning with a concise outline of the history and biological significance of fingerprints, the author leads to the procedure for taking fingerprints, ridge counting, tracing and filing, etc. A detailed account of new methods of uncovering latent fingerprints and their application in criminal investigation is an outstanding feature of the book. Careful inspection and tests decide the method and materials to be used in retouching a fingerprint. Forty-eight different powder materials and twelve powder formulas are listed with instructions for their use in the "powdering fingerprint method". A photograph of the fingerprint prior to and at several stages in its development is first recommended. The method of "lifting latent fingerprints" offers advantages when prints are found in places where they cannot be photographed successfully. This technique and the materials necessary are explained fully. Another "fuming process method" plus "ink", "heat" and "casting" methods covers the subject of latent fingerprints with the latest facility of modern science. A full explanation is given of the Vucetich and the Henry systems of filing and classification, both of which serve as a basis for most other methods.

The work is authoritative being written by a specialist who served a number of years as instructor in this branch of science. It should be useful for police personnel, civic and state officials, students in police recruit training schools, and in colleges having law enforcement courses.

IN ALASKAN WATERS.

By Alfred Wolfe. The Caxton Printers, Caldwell, Idaho. $3.00. 9 x 6; 196; 1942.

In this very interesting book Mr. Wolfe, a fisherman of long experience, gives us in simple direct words a clear account of his numerous trips fishing for deep sea salmon and halibut off Cape Flattery and British Columbia in the summer, and as far north as southeastern Alaska in the winter. The various methods of deep sea fishing are explained and illustrated with accuracy and detail. Up until 1914, the old style type of dory fishing was used entirely. About this time a new method came into use, the "long line system" in which the setting and the hauling of the gear and nets was done directly from the vessel—one of the chief advantages being that men could fish with much less hard labor and in much worse weather than possible when dories were used.

The trips described lasted from two weeks to two months with a catch varying from a few pounds to a

lucky twelve hundred thousand with a good profit shared equally.

One small but interesting incident centers around the catching of a rare "left-handed" halibut with gills and all organs located on the left side instead of on the right as normally. Only three of this type were ever seen in his long experience.

The author discusses at length the "worst marine disaster in the history of the Pacific coast"—the sinking of the Princess Sophia near the end of World War I with a 100 percent loss of life.

From reading this book one cannot help but be impressed with the courage, fortitude, resourcefulness, and endurance exhibited by these fishermen who make their living in these dangerous waters.

THE CLARKS. *An American Phenomenon.*

By William D. Mangam. With an Introduction by Edward Alsworth Ross. Silver Bow Press, New York. $2.50. 8 x 5⅜; ix + [257]; 1941.

If the unsuspecting reader should feel that it is impossible that the limits of a single family should embrace such a high concentration of immorality as the author attributes to the Clarks, let him recall that the latter were endowed with sufficient wealth to prosecute a libel suit, had there been the least doubt as to the accuracy of the author's statements.

Perhaps the most striking disclosure made in the entire book is that one of the Clarks kept a mistress, not for the purpose which mistresses ordinarily serve, but as a red herring to draw across the trail in case the police became too inquisitive about the practices indulged in behind his closed doors. He considered the reputation he was able to enjoy as the result less malodorous than the one he would have acquired if the facts on his way of living became public property.

Reviews of pornographic literature are not new to these columns, but all previous examples pale into innocuous innocence when viewed in the light of the lurid hues of this masterpiece. One wonders why the author did not employ his talents in a worthier task.

To the Clark family is hereby unanimously awarded the gold-plated gas mask.

NEEDLE TO THE NORTH: *The Story of an Expedition to Ungava and the Belcher Islands.*

By Arthur C. Twomey, in collaboration with Nigel Herrick. Houghton Mifflin Company, Boston. $3.50. 9 x 6; viii + 360; 1942.

Needle to the North is a vivid account of a scientific expedition to Ungava and the Belcher Islands, located in the sub-arctic region of the Hudson Bay and the northern half of the Labrador Peninsula. These desolate regions, unheard of by the general reader, have long lain unchanged and uncharted.

The book, divided into two sections, first tells of Ungava and describes the quest of the mysterious unknown inland sea "Kasogea", which is almost a legend. Twomey, an ornithologist, and Doutt, mammalogist, both of the Carnegie Museum, experienced considerable adventure, difficulties and human drama before their purpose was successfully accomplished. The scientific report on Kasogea has not yet been published.

The second section of the book is concerned with the Belcher Islands, and their strange and primitive peoples. Civilization came late to the Belcher Island Eskimo, yet his very sensitive mind and adaptability to new ways, makes him already a doubtful example of a natural igloo-man. "Before you would dare assume that he has learned to use it, the hunter of the Belchers will make your mechanical gadget an integral part of his life". The author describes, among his experiences in the Belcher Islands, the quick change from the long winter to the short spring and summer with its numerous flowers, buds, insects, etc., which come to life for this brief season.

FAMILY EXPENDITURES FOR CLOTHING: *Five Regions. U. S. Department of Agriculture Miscellaneous Publication No. 422. Consumer Purchases Study. Urban and Village Series.*

By Maryland Y. Pennell, Day Monroe, Kathryn Cronister, Geraldine S. DePuy, and Marjorie W. Ellsworth. Government Printing Office, Washington, D. C. 35 cents. 9¼ x 5¾; iii + 329; 1941.

CHANGES IN ASSETS AND LIABILITIES OF FAMILIES: *Five Regions. U. S. Department of Agriculture Miscellaneous Publication No. 464. Consumer Purchases Study. Urban, Village, and Farm Series.*

By Dorothy S. Brady, Day Monroe, Janet Murray, Yetta A. Carmel, and Marjorie Ellsworth. Government Printing Office, Washington, D. C. 25 cents. 9⅛ x 5¾; v + 226; 1941.

FAMILY EXPENDITURES FOR HOUSING AND HOUSEHOLD OPERATION: *Five Regions. U. S. Department of Agriculture Miscellaneous Publication No. 457. Consumer Purchases Study. Farm Series.*

By Hazel Kyrk, Day Monroe, Dorothy S. Brady, Colette Rosenstiel, and Edith Dyer Rainboth. Government Printing Office, Washington, D. C. 25 cents. 9⅛ x 5¾; v + 201; 1941.

In all three of these reports the first part deals with a discussion of the scope and organization of the study and the general summary of the findings, with the data collected exhibited in detail in tables in the latter part. In each case a wealth of material has been collected and has been so arranged that future workers along these lines will find the present study of great usefulness.

ZOÖLOGY

ANIMALS ARE MY HOBBY.

By Gertrude Davies Lintz. Robert M. McBride and Company, New York. $2.75. 8 x 5½; 301; 1942.

This is the entertaining and at times instructive autobiography of an unusual woman who admits frankly that "rare animals—from difficult to impossible ones—have been the irresistible lure of my life. Just as some women are most attracted by problem children, I am attracted by problem animals." In her New York home Mrs. Lintz has brought up sixteen great apes, including the now much advertized gorilla "Gargantua", over two hundred St. Bernard dogs, and a random assortment of other animals. The largest and most interesting part of the book deals with the lives of the anthropoid apes who enjoyed amazing freedom and devoted care in the writer's extraordinary household, where they thrived in spite of many an initial illness. Mrs. Lintz's remarkable success in raising her many simian *prima donnas* was due chiefly to her full appreciation of the need of these apes for companionship, entertainment, and exercise, factors which are all too frequently ignored in zoological gardens. For the author's great devotion nothing appears to have been too much; with a sick baby mountain gorilla she patiently tried to "pinch-hit for a mother gorilla" by chewing food into a soft pap until her jaws ached and then transferring it to the gorilla's mouth. Incidentally, this ape was regarded by Mrs. Lintz as "the most feminine creature in the house," but was really a male who grew to huge size. Eventually he had to be sold to a Zoo, though not until sometime after he had severely mauled his benefactor. Like nearly all apes, Gargantua also became untrustworthy with advancing age and had to be confined in a welded steel cage in the Lintz sun parlor. He had passed the 400-pound mark when one night he escaped and made a bee-line for the author's bedroom. That she got him back safely is a miracle and the account of it is very worth reading.

The author summarizes her unique experiences by maintaining that the gorilla always wants to keep the peace and that if he is not "a man on his way up, to me he seems a brother." Quite evidently she thinks more highly of all her apes than of some human beings—no wonder, since two of her apes were poisoned and one had acid thrown over him and later was given acid to drink by mean human morons.

Some of the illustrations are excellent and many of the chapters contain accurate descriptions of the psychological nature of the two great African apes.

ORNITHOLOGISTS OF THE UNITED STATES ARMY MEDICAL CORPS. *Thirty-six Biographies.*

By Edgar Erskine Hume. With a Foreword by Alexander Wetmore. The Johns Hopkins Press, Baltimore. $5.00. 10⅞ x 7⅞; xxv + 583; 1942.

It was under the guidance and encouragement of Spencer Fullerton Baird, Assistant Secretary of the Smithsonian Institution from 1850 to 1878 that many young surgeons of the Army Medical Corps developed an interest in birds. Baird assisted many of these by suggesting details and assignments for expeditions during the period of the opening up of the West. The names and contributions to systematic ornithology of Coues, Bendire, Cooper, Heermann and Mearns are familiar to most ornithologists of the present generation. It is also a rather well-known fact that the army stations and travels of these men in the West gave them the opportunities of pioneers in the study of birds. That we can add to the contributions of these great men those of many others from the same branch of the military service is, however, probably somewhat surprising to most students of bird life.

Colonel Hume has collected in the present volume a great store of information about the thirty-six men of whom he writes. He has obtained much valuable and interesting data from the archives of the Army Medical Corps which give us information not heretofore publicly known. The biographic sketches are interestingly written and briefly summarize the activities of these men, both from the point of view of their army duties and their ornithological interests. In many cases extracts of their writings are given. These include very interesting descriptions of explorations both in this country and abroad. Each biography contains one or more illustrations of the subject, and there are many historically interesting photographs and sketches of old army posts.

Indeed we have in this volume a kind of "personal bibliography" of the development of ornithology in this country during the nineteenth and early part of the twentieth century. In the words of the author, "It is hoped that these bibliographies of medical officers of the United States Army who have contributed to ornithology will establish one more record of achievement for the Medical Department in a highly specialized field of science." The book is of unusual value both to the medical historian and to the student of bird life.

LIFE HISTORIES OF NORTH AMERICAN FLYCATCHERS, LARKS, SWALLOWS, AND THEIR ALLIES. *Order Passeriformes. United States National Museum Bulletin 179.*

By Arthur Cleveland Bent. Smithsonian Institution, Washington, D. C. $1.00. 9½ x 6; xi + 555 + 70 plates. 1942 (paper).

This is the fourteenth in a series of bulletins of the United States National Museum on the life histories of North American birds. The general plan and method of presentation of the data are the same as that followed in previous bulletins, and the same sources of information have been utilized. The nomenclature of the 1931

check-list of the American Ornithologists' Union has been followed.

Life histories of the best-known subspecies of each species are given as completely as possible. To avoid duplication in describing the others only the characters of the subspecies, its range, and any life habits peculiar to it are included. In many cases certain habits which are probably common to the species as a whole have been recorded for only one subspecies. These are described for the species on which the observations have been made. The distribution of the species as a whole is given, with only rough outlines of the ranges of the subspecies, which in many cases cannot be accurately defined.

The data on each species are usually arranged under the following headings: Courtship, Nesting habits, Eggs, Plumages, Food, Voice, Field marks, Distribution (including spring and fall migration dates). The plumages are described in only enough detail to enable the reader to trace the sequence of molts and plumages from birth to maturity and to recognize the birds in the different stages and at the different seasons.

In addition to the excellent treatment of the life histories and habits of these interesting American birds there are seventy plates of collected photographs. These are of the usual high quality found in this series of bulletins. Many of the birds, their nesting habitats and nests are illustrated. No small part of the value of this bulletin lies in its plates.

CATALOG OF THE TYPE SPECIMENS OF MAMMALS IN THE UNITED STATES NATIONAL MUSEUM, INCLUDING THE BIOLOGICAL SURVEYS COLLECTION. *Smithsonian Institution, United States National Museum Bulletin 178. By Arthur J. Poole and Viola S. Schantz. Government Printing Office, Washington, D. C.* $1.25. 9¾ x 6½; xiii + 704; 1942 (paper).

In 1901 the first type list of mammals in the United States National Museum was published (*U. S. Nat. Bull.* 62, 325). The present volume, the second such catalog to be issued, includes also those specimens now in the collection made by the Fish and Wildlife Service (the two collections are kept separate but are in adjoining laboratories). A total of 2,824 type specimens are listed of which 1,409 are new additions since the publication of the first type list. Large series of specimens have been used in the work, and nearly every prominent mammalogist, so the authors say, is represented—Audubon, Allen (J. A.), Baird, Cope, LeConte, and others of the earlier period; Bailey, Howell (A. H.), Lyon, Merriam (C. H.), Miller, and many others of more recent times. While numerous expeditions have contributed to the collection, the type specimens of the Malayan and African mammals have come from two main sources, namely the Malayan explorations of the late Dr. W. L. Abbott (1897–1909) and the Smithsonian and Rainey African expeditions (1909–1910, 1911–1912). The older type specimens of North American mammals have also come from two main sources, those collected about the middle of the nineteenth century by governmental exploring parties and those recently collected by the Biological Survey.

The material is well arranged and the catalog will be of great usefulness to those who have occasion to consult it. At a glance all the necessary information about any desired form is available: place and date of original description, U. S. Nat. Mus. catalog number, nature of specimen (whether there is present skin, skull or other parts of skeleton; how preserved, etc.), age and sex, locality, date of collecting, name of collector, original number of specimen, date when cataloged, and condition of specimen at present time.

REPRESENTATIVE NORTH AMERICAN FRESH-WATER FISHES. *By John T. Nichols. Illustrated by Andrew R. Janson. The Macmillan Company, New York.* $1.25. 6½ x 4; 128; 1942 (paper).

This little vest-pocket book is designed to aid the angler, or anyone else interested, in the identification of the common types of North American fresh-water fishes and to afford him some information concerning their habits and habitats, their adaptations and their evolutionary relationships. The book consists of sixty full-page illustrations, half of them in color, of representative fishes, with a single page of text accompanying each figure. The illustrations are uniformly excellent and the amateur should find it easy to make an approximate identification of any specimen which comes to hand, simply by comparison with the figures. This being the case, there has been no attempt to provide a key or to give a detailed description of taxonomic characters. Instead the text is mainly devoted to accounts of interesting habits or adaptations of the fish under consideration or to general ichthyological problems which it suggests. Thus the discussion of the paddlefish (*Polyodon*) provides an opportunity for some account of relict species; the evolution of the swim-bladder into a respiratory apparatus is considered in connection with the bowfin (*Amiatus*) and the migrations of anadromous and catadromous fishes are discussed in the sections on the shad and the eel. In this way Nichols has been able, in a very short space, to give information on such a wide variety of subjects as breeding habits, nest building, concealing coloration, the inheritance of albinism and the evolution of the cave-fishes. The text is written in a simple straightforward style with no attempt to "talk down" to the layman.

This reviewer feels that the book fulfils most admirably the double function which such a brief introductory work should have. It provides a clear and useful means for ready identification of specimens while at the same

time effectively stimulating interest in the broader aspects of ichthyological science.

THE RAT *in Laboratory Investigation.*

Edited by John Q. Griffith, Jr. and Edmond J. Farris. By a Staff of Thirty Contributors. J. B. Lippincott Company, Philadelphia and London. $7.50. 9 x 6; xiv + 488; 1942.

The albino rat is the most widely used laboratory animal today. It has been found to be an ideal animal for research in many disciplines of experimental biology. A volume, such as this one, which emphasizes techniques and procedures, has been needed for a long time. It is thus destined at the outset to serve a useful purpose.

Some of the numerous and varied subjects treated by the different authors are: breeding, gross anatomy, embryology, diet, teeth, digestive system, metabolism, central nervous system, psychology, circulatory system, bio-assay, hematology, histology, surgery and parasitology. The chapters on gross anatomy, dietary requirements, teeth, and surgery are particularly complete. In almost all chapters experimental methods and techniques receive the major emphasis. The illustrations are numerous and well selected. A useful bibliography is provided at the end of each chapter. The index is adequate.

Naturally many of the methods applied to, and conclusions derived from, work on rats, while having particular reference to investigations on the rat, are applicable to experimental work in general. The book should be useful, therefore, not only to investigators who work with rats but also to general mammalian physiologists, histologists, etc.

In many institutions the rat is as familiar to the teacher as to the investigator. Those who teach experimental subjects in the biology curriculum will, therefore, find this volume an excellent reference work. The book is one which is to be highly recommended to investigator, teacher and student alike.

THE LIFE OF LANGSTROTH.

By Florence Naile. Edited, with a Foreword and an Introduction by Everett Franklin Phillips. Cornell University Press, Ithaca. $2.50. 8½ x 5⅝; 215; 1942.

Lorenzo Lorraine Langstroth, the "Father of American Beekeeping," was born in Philadelphia in 1810 and died in 1895. He was educated at Yale and ordained to the Christian ministry, which he practiced for several years until ill-health unfitted him for a regular charge. He then took up beekeeping which had already interested him as a hobby. His studious observations of the habits of bees led to his invention of the removable-frame hive and the publication, in 1853, of *The Hive and the Honey Bee*, the first American handbook for beekeepers. He also was a prolific contributor of articles to the *American Bee Journal* and *Gleanings in Bee Culture* from the time of their foundation in 1861 and 1874, respectively. And he took part in the long-continued, but eventually successful, attempts to import Italian bees and to naturalize them in this country. This is the outline, in brief, of Langstroth's life and work and, until the publication of this book, represents about all (or more) that was generally known about him. Miss Naile is his first biographer. There is evidence of painstaking study of source material for collecting and putting in order the less known facts of Langstroth's life, but the book is not dull. In fact, it should be of interest even to those who have no intimate knowledge of beekeeping.

THE COMMERCIAL FISH CATCH OF CALIFORNIA FOR THE YEAR 1940. *State of California, Department of Natural Resources, Division of Fish and Game, Fish Bulletin No. 58.*

By the Staff of the Bureau of Marine Fisheries. California State Printing Office, Sacramento. 9 x 6; 47; 1942 (paper).

This is the seventh of a series of "Catch Bulletins." These are issued for the purpose of making available the summaries of commercial fish landings in each region of the State of California. Aside from the data on pounds of fish landed (these are given separately for each kind of fish) the reports are of considerable interest from several points of view. Data are included concerning numbers and nativity of commercial fishermen and number of boats of each type engaged in the fishery; the shifting from one type of fishing to another (a notable example of this is the rapid development of the shark fishery because of the high price offered for the liver oils); the development of sport fishing with its requirement of small fish for bait—chiefly sardines and anchovies. In 1940, 2389 tons of live bait were used for this purpose.

The total pounds of fish landings for 1940 came to 1,296,048,348; for 1939 the catch was very nearly 200 million pounds greater. This large withdrawal of fish from California waters each year must have, over a period of years, a profound effect on the fish population of the region.

THE INTERNATIONAL PROTECTION OF WILD LIFE: *An Examination of Treaties and Other Agreements for the Preservation of Birds and Mammals.*

By Sherman Strong Hayden. Columbia University Press, New York. $3.00. 8¾ x 5¾; 246; 1942.

When an animal maintains a seasonal migration across several sovereign states it can be conserved only by

international treaty. At a time like this when there is so much international dissension and where national policies conform to present wants rather than to future needs, it seems impossible that any sort of agreement for the preservation of wild life could be reached. It is true that the outlook for seals, whales, and migratory birds looks black, but it is by no means hopeless.

In this work is told the story of what has been done in the past, both by reciprocal agreement and through the League of Nations, and the average reader is likely to be surprised by the advances that had been made prior to the beginning of the present war. But it must be remembered that that was only a beginning, and that when sanity returns to a warring world it will be necessary to have some more international agreements.

The book is amply documented and well worthy of serious study.

PRAIRIE DOG TOWN.

By Margaret Thomsen Raymond and Carl O. Mohr. Dodd, Mead and Company, New York. $1.50. 8¾ x 6½; 56; 1942.

The life story of Mr. Prairie Dog is here recounted for the youthful reader. His day to day activities are followed from his infancy to the time when he assumed the onerous responsibilities of a family head. The industry and ingenuity with which he builds his burrow and his constant wariness in avoiding his enemies are absorbing topics and one soon comes to respect Mr. Prairie Dog as an independent and self-reliant little chap who, even in times of greatest hardship and danger, is filled with the joy of living. The book is illustrated by an excellent series of photographs of prairie dogs and their neighbors, the burrowing owl, the prong-horn antelope, the jack-rabbit and others. The prairie dog's enemies are also portrayed; the hawk, the ferret, the coyote, the badger and the rattlesnake. In addition there is a series of lively sketches of some of the activities of these animals. This is a fine example of the best type of nature book for children.

HORNS AND ANTLERS.

By Wilfrid S. Bronson. Harcourt, Brace and Company, New York. $2.00. 8½ x 6; 143; 1942.

The natural history of the North American deer and antelopes is here set forth in the same engaging style which distinguishes Mr. Bronson's book on the rodents. Sympathetic interest and painstaking, accurate observation have combined to produce a lively and authoritative picture of the habits of the various native ruminants of this continent and to bring out the differences between them. Separate chapters are devoted to consideration of the whitetails, the mule deer, the wapiti, the moose, the reindeer and caribou, the prongbucks and the mountain "goats." The author's well-known paintings of natural history of subjects are represented by four full-color plates and 46 black and white illustrations.

This is a work which will prove of special interest to the student of natural history and to the hunter. Moreover, because of the large amount of first-hand information about the habits of the deer family which it contains, it will be a useful reference book for the professional zoologist.

NOTES ON A COLLECTION OF FISHES FROM ANTIGUA AND BARBADOS, BRITISH WEST INDIES.

By Albert W. C. T. Herre. Stanford University Press, Stanford University, California; Oxford University, London. $1.25. 9¾ x 6¾; 21; 1942.

The identification and description of some 90 species of fish representing 68 genera and 41 families, collected by Dr. Walter K. Fisher in 1918 from the waters around Barbados and Antigua, is successfully undertaken in this report. The difficulties inherent in measuring and describing the colors of various specimens of fish which have been preserved for nearly 25 years are indicative of the laborious and painstaking observations essential to a study of this sort.

In addition to the listing of measurements, colors and sites of collection for each species, the author includes pertinent discussions on the minor distinctions between various forms, the errors in earlier taxonomic works, and the value of further studies of the fish from this region.

The work carries a short table of contents, but no index.

ZOOLOGICA. *Scientific Contributions of the New York Zoological Society. Vol. XXVII, Part I, Numbers 1–8. New York Zoological Society, Zoological Park, New York.* 75 cents. 10½ x 7; 48 + 5 plates + 1 folding map; 1942 (paper).

This number contains the following papers:

Social and respiratory behavior of large tarpon, by C. M. Breder, Jr. (1 text figure); Tetanus in an elephant (*Elephas maximus*), by Leonard J. Goss; Descriptive ecology of La Cueva Chica, with especial reference to the blind fish, *Anoptichthys*, by C. M. Breder, Jr. (1 text figure and 3 plates); Quantitative serologic relationships within the Artiodactyla, by Joseph G. Baier, Jr. and Harold R. Wolfe (1 text figure); Observations on the electric discharge of *Torpedo occidentalis*, by C. W. Coates and R. T. Cox, (4 text figures); The Ampulicidae and Sphecidae (Sphecinae) taken at Kartabo and other localities in British Guiana. (Hymenoptera), by H. T. Fernald; A Résumé of Mexican Snakes of the Genus *Tantilla*, by Hobart M. Smith; Eastern Pacific expeditions of the New York Zoological Society. XXX. At-

lantic and Pacific fishes of the genus *Dixonina*, by William Beebe (2 plates).

THE ANIMAL BOOK: *American Mammals North of Mexico.*

By Dorothy Childs Hogner and Nils Hogner. Oxford University Press, New York and London. $3.50. 10⅜ x 8; 223; 1942.

This is a handbook of mammals living on the North American continent and in adjacent waters north of Mexico. The habits, appearance, and range of about one hundred and seventy mammals, both familiar and unfamiliar, are described in a simple, direct, accurate manner for juvenile readers. The material was compiled from first-hand study of the animals, much of it during "travel with a tent and camp kit over many sections of the continent."

The illustrations, more than one hundred pen-and-ink sketches in black-and-white, by the author's artist husband are an essential part of the work. This book should be useful in schools, camps, libraries, or any place where accurate accounts and pictures of North American mammals are needed for young folks.

THE TALE OF THE PROMETHEA MOTH.

By Henry B. Kane. Alfred A. Knopf, New York. $1.25. 9 x 7; 24 unnumbered pages + 22 plates; 1942.

This beautiful little book is the third volume in the "Wild World Tales" series by Kane in which once more he combines facts, beautiful photographs and attractive pen-and-ink sketches to give his readers a true and exciting story of nature.

The Promethea is one of the largest, handsomest and most common of the great moths, and unlike many of them, flies in the late afternoon at dusk. The account of its interesting life-cycle is given so simply and beautifully that it will interest mature as well as young readers. The twenty-three full-page photographic illustrations accompanying the text are particularly fine in both composition and detail and alone are well worth the price of the book.

WONDERS OF THE SEA.

By Gladys Pratt Freund. Illustrated by Rudolf Freund. Random House, New York. $1.00. 11 x 9; 36; 1942.

This very colorful book is designed primarily for introducing to juvenile readers a few of the more spectacular of the animals and plant-like animals that live in the ocean.

Some of the "wonders" selected by the author for description and illustration are: sponges, corals, sea anemones, giant clams, cephalopods, barnacles, jelly fish, various "queer fish" such as puffers, flying fish, angler fish, deep sea luminous fish, and the giant whales, porpoises and dolphins. The book contains a good deal of basic information and is interesting to read.

More than a dozen full-page, highly-colored decorative drawings by Rudolf Freund illustrate the test.

AMERICAN BUTTERFLIES AND MOTHS.

By Cecile Hulse Matschat. Illustrated by Rudolf Freund. Random House, New York. $1.00. 11 x 8¾; 70; 1942.

In this artistic, tastefully arranged and practical book, the author has given us the complete life-story of seventy-three of our most common butterflies and moths. The detailed descriptions aided by reference to numbers of full-color plates and black-and-white sketches by Rudolf Freund enable one to identify with ease the butterflies and moths seen in gardens, parks, and on walks in the fields and woods. The author has had considerable experience as a naturalist both in Latin America and in this country. The book is not intended for specialists but rather to introduce these most fascinating of all insects to nature lovers.

BRITISH BIRDS *on Lake, River and Stream.*

By Phyllis Barclay-Smith. With sixteen colour plates after the originals in The Birds of Great Britain by John Gould. Penguin Books, Ltd. Harmondsworth, England. 25 cents. 7⅛ x 5⅛; 31 + 16 plates; 1941.

This popular little book contains sixteen color plates reproduced from the originals in *The Birds of Great Britain* by John Gould. The colors and composition of the plates are good. In addition to the plates the book has a brief biographic sketch of the life of John Gould, the well-known British and Australian ornithologist. There are also very brief but interestingly written descriptions of the life habits of the sixteen bird species. Only the most common fresh-water birds are described.

TRANSACTIONS OF THE SAN DIEGO SOCIETY OF NATURAL HISTORY. *Volume 9, Nos. 32 and 33. A Vertebrate Faunal Survey of the Organ Pipe Cactus National Monument, Arizona*, by Laurence M. Huey; *Notes on Some Mexican and Californian Birds, with Descriptions of Six Undescribed Races*, by A. J. van Rossem.

Society of Natural History, San Diego, Calif. 10¼ x 6⅞; No. 32, 21; No. 33, 8; 1942 (paper).

OFFICIAL ILLUSTRATED GUIDE BOOK TO THE PHILADELPHIA ZOOLOGICAL GARDEN.

By Roger Conant. Zoological Society of Philadelphia. 25 cents. 8⅜ x 5½; 107; 1941.

BOTANY

HOME VEGETABLE GARDENING.

By Charles H. Nissley. With an Introduction by William H. Martin. Illustrated by Ruth Nissley. Rutgers University Press, New Brunswick, N. J. $1.50. 7¾ x 5; x + 246; 1942.

25 VEGETABLES ANYONE CAN GROW.

By Ann Roe Robbins. Illustrated by Leonard J. Robbins. Thomas Y. Crowell Company, New York. $2.25. 9¼ x 6; xii + 219; 1942.

THE FOOD GARDEN.

By Edna Blair. Illustrated by Laurence Blair. The Macmillan Company, New York. $2.00. 10 x 9½; 148; 1942.

All three of these books belong in the "how-to-do-it" category and were written for those persons whose first venture at vegetable growing is the Victory garden. *Home Vegetable Gardening* is the most comprehensive of the three. In addition to the specific instructions for growing each of more than 60 vegetables and herbs, it contains preliminary chapters on gardening equipment, the selection of seed, preparing and improving the soil, growing early plants for transplanting, storing vegetables for winter use, and garden pests and their control. A supplementary chapter gives instructions for saving and treating seed.

Mrs. Robbins' book contains brief, but adequate, information on the history, food values, culture, and habits of growth, storing, canning, and recipes for cooking each of the 25 vegetables as well as giving directions for their planting and cultivation. It is provided with a washable cover and may be used and consulted out in the garden.

The third book is the most profusely illustrated. The directions given for the growing of most of the 49 vegetable and salad plants, 16 herbs and 17 fruits and berries selected by the Blair's for discussion, are accompanied by series of drawings depicting various steps in their cultivation.

PROPAGATION OF PLANTS. *A Complete Guide for Professional and Amateur Growers of Plants by Seeds, Layers, Grafting and Budding, with Chapters on Nursery and Greenhouse Management. Revised and Enlarged Edition.*

By M. G. Kains and L. M. McQuesten. Orange Judd Publishing Company, New York. $3.50. 9 x 6; xi + 639; 1942.

As the original edition of this standard reference book was published 22 years ago and is now both out of date and out of print, this revision fills a definite need. It has been considerably enlarged and changes and corrections have been made throughout to conform with the most recent data available from a review of the world literature in this field. "The text has been so arranged that the propagator . . . can get a clear exposition of whatever subject interests him, without being annoyed by pedagogical material . . . the teacher, the experimenter, and the student will find abundant reference to text and illustrations in the 50 practicums placed toward the close of the book." In addition to the detailed discussions of methods of aiding germination, seed testing, various kinds of propagation, pest control and so forth, there are plant lists and condensed rules for propagation of special value when unfamiliar plant material is being dealt with, and a list of Federal and State regulations and quarantines. The addition of new illustrations brings the total to 350 plates, many of which contain two or more pictures. Unfortunately, not all of these are clear enough to enable the easy perception of details. References to tables, illustrations and the institutions and authors whose work has been cited in the text are listed in the same index as the subjects and plant varieties discussed.

A TEXTBOOK OF BACTERIOLOGY. *Third Edition, Revised.*

By Thurman B. Rice. W. B. Saunders Company, Philadelphia and London. $5.00. 9⅛ x 5⅞; xii + 560; 1942.

The stated purpose of this text (cf. Q. R. B., V. 11, p. 104 and V. 14, p. 90 for notice of earlier editions) is to serve as a practical aid to the general practitioner or student who might wish a full understanding of the subject, but who cannot find time to go into all the five theoretical points. It is a practical rather than a theoretical text. By a thorough sifting of material, the author has obtained a very condensed treatment. Morphological and cultural characteristics are held to real essentials. The emphasis is rather on disease characteristics with efficient diagnosis, prognosis treatment and general management as the end.

Although the present edition has been brought up to date to some extent, there are no extensive changes in the text material. Slight additions have been made in some chapters as, for example, in those of rickettsia, filterable viruses, etc. Information on "special bacteriology," collection of samples, etc., is appended. There is a useful index, but unfortunately no bibliography, a regrettable omission in view of the condensed nature of the text.

This book should be of great use both for beginners, as an introduction, and for more advanced students and practitioners, as a practical review book.

SOYBEANS: *Gold from the Soil.*

By Edward Jerome Dies. The Macmillan Company, New York. $1.75. 8 x 5⅜; 112; 1942.

Although soy bean culture in China was ancient when Abraham resided in Ur of the Chaldees its introduction to the western world is of such recent date that a brief volume is adequate to cover its history and to recount some of the purposes to which it is adapted.

The importance of the soy bean as a foodstuff is due to its high proteid and vitamin B content, and its low starch content. Agriculturally it is of importance because it requires less care between planting and harvesting than most crops, and its industrial significance may be judged from the fact that one automobile manufacturer is seriously considering it as a source of plastic from which bodies may be constructed.

Although only one species of soy bean is known, 126 varieties have been introduced into the United States, which differ in their proportions of oil, starch, number of beans to the pound, age at maturity, etc. Several pages of comparative statistics are given, but owing to the lack of probable errors it is impossible to tell whether the varieties are really distinct or not.

The book is well provided with graphs illustrative of the fluctuations in value and size of crops from year to year, and a bibliography of over 200 items adds to its usefulness.

TEXTBOOK OF DENDROLOGY: *Covering the Important Forest Trees of the United States and Canada. Second Edition.*

By William M. Harlow and Ellwood S. Harrar. McGraw-Hill Book Company, New York. $4.50. 8⅛ x 6; xv + 542; 1941.

The major changes that have been made for this edition are the inclusion of range maps for all the species set in text type and tables of "distinguishing characteristics" for groups of these species. The nomenclature in the first edition followed the American Code. In consideration of the recent adoption of the International Code by the United States Forest Service, appropriate changes and additions have been made in the nomenclature used in the present edition. As the book is designed for use in a beginning course in forestry only, the species of greatest importance to forestry, commerce and industry in this country are treated. Numerous excellent photographs and drawings clarify the text. The authors have provided a glossary, a list of bibliographical references, selected for their significance or recency, and an index which indicates also the pages where half-tone illustrations of the item in question occur.

ITINÉRAIRES BOTANIQUES DANS L'ILE DE CUBA: (*Première Série*). *Contributions de l'Institut Botanique de l'Université de Montréal, No. 41.*

By Frère Marie-Victorin and Frère Leon. Institut Botanique de l'Université Montréal, Montréal. $2.50. 9 x 6; 496 + folding map; 1942 (paper).

As part of its active program of research work, The Botanical Institute of the University of Montreal organizes expeditions to various locations in the western hemisphere for the purpose of identifying, collecting and studying the native flora of the region. The present monograph, number 41 in The Institute's series of publications, is a report of just such an expedition to Cuba in 1939. The geographical, physiographical and geological features of the island are considered in relation to the ability of various types of terrain to support plant life. Then, in log form, the work presents the chronological activities of the expedition as it covered its extensive itinerary. Particular note is made of the taxonomic, physiological, ecological, and pathological characteristics of the flora of a considerable portion of the island.

The work is profusely illustrated with photographs, charts and maps showing the distribution of the various species of plants. A large gatefold, cross-key map of Cuba, for ease in locating points of interest in the expedition, and an index of scientific names are appended.

SCIENCE IN THE GARDEN.

By H. Britton Logan and Jean-Marie Putnam, in consultation with Lloyd C. Cosper. Foreword by Dr. F. W. Went. Duell, Sloan and Pearce, New York. $2.50. 9½ x 5½; xiv + 255; 1942.

The first three chapters of this book sketch briefly some of the major discoveries from early times to the present that have aided in the development of scientific gardening. The other chapters are more specific with respect to the various phases and chores in the propagation of plants, such as polinization and the evolution of new plants, chemical acceleration of seed germination, pruning, the effects of light, vitamin B_1, colchicine and other substances on plant growth, and the like. In pointing out the scientific basis for many of the chores of the gardener, the authors explain, wherever possible, the "why" as well as the "how" of the procedure in question. Numerous experiments that may be carried out with little equipment and small space are suggested and outlined in the last chapter. Written for the layman who is interested in "dirt gardening," the book is authoritative and it is hoped will inspire new contributions to the science of plant propagation.

CHEMICAL GARDENING. *Latest Developments in Soiless Culture of Plants.*

By D. R. Matlin. Chemical Publishing Company, Brooklyn. $2.25. 8½ x 5½; vi + 159; 1942.

Chemical Gardening is a new 150-page manual for the popular occupation of growing plants in liquid and sand cultures. This book compares very favorably with earlier publications on soiless gardening in that it is mainly factual, less extravagant in claims and less superficial in its treatment of basic principles of plant culture than most publications on this subject. A great deal of practical general information on techniques of preparing and caring for soiless plant cultures is concisely presented in 13 separate chapters.

Several nutrient formulae, charts of mineral deficiency and toxicity symptoms, brief treatments of the function of elements and the use of insecticides, etc. are included. The types of equipment and procedures suited for commercial protection and home use are presented separately. The book therefore may be of considerable value to home gardeners in general.

HISTOIRE DE L'INSTITUT BOTANIQUE DE L'UNIVERSITÉ DE MONTRÉAL 1920–1940. *Contributions de l'Institut Botanique de l'Université de Montréal*, No. 40.

By Frère Marie-Victorin. Institut Botanique de l'Université de Montréal, Montréal. $1.00. 9 x 6; 70; 1941 (paper).

The historical development, scientific activities and publication, personnel, and probable future of The Botanical Institute of the University of Montreal are discussed in detail in this published form of Frère Marie-Victorin's presidential address delivered before the Canadian Society of Natural History, at the Botanical Garden of Montreal, in February, 1940.

The rapid growth of The Institute during the past 20 years, the excellent service it has performed, and the impressive list of publications (this is the 40th) are indicative of a sound foundation and able leadership. We can rightly expect the future contributions of The Institute to be of the same high quality as those of the past. Numerous photographs of the buildings, staff, and classes of The Institute are included in the volume.

CONE-BEARING TREES OF THE PACIFIC COAST.

By Nathan A. Bowers. Whittlesey House, McGraw-Hill Book Company, New York and London. $2.50. 8 x 5¼; ix + 169; 1942.

Realizing a real need for something in between the technical treatise and the sketchy "popular" material, the author has prepared this comprehensive yet non-technical field manual for the use of non-botanical tree lovers on mountain trips and in rambling through the forests of the Paicfic slope. He offers three keys to identification—the Needle Key, the Elevation Key and the Geographical Key—with complete directions for their use.

The greater part of the book is taken up with descriptions of the various species conveniently grouped according to geographic districts. There are 57 full-page plates, a glossary and an index.

PLANT BIOLOGY.

By Paul Weatherwax. W. B. Saunders Company, Philadelphia and London. $3.25. 8¾ x 5¾; vi + 455; 1942.

This book has been designed as a text for a one semester course in botany or for the botany part of a generalized course in biology. Actually, it contains more material than can be covered in a short course, but the material is so arranged that parts, such as the chapters on the great groups of plants, can be omitted or modified to suit the aims of the individual teacher. There is a glossary, with pronunciation indicated, of terms used exclusively in biology or that have some special meaning when used in that field which the student should know—the list is not confined to words used in this text. The book is profusely illustrated with photographs and line drawings, many of them by the author himself.

PLANT LIFE. *A Textbook of Botany. Second Edition.*

By D. B. Swingle. D. Van Nostrand Co., New York. $3.00. 9 x 6; xvi + 457; 1942.

The main emphasis in this text is upon the physiology and behavior of plants. It has been prepared for use in a short course in botany, affording students who do not intend to continue the subject further with a good knowledge of the fundamentals and those who do an excellent background for advanced study. The revision consists mainly in the introduction of a little more natural history than the first edition contained, amplification of portions that experience has proved were treated too briefly for clearness, and the addition or substitution of a few new illustrations.

CONTRIBUTIONS DE L'INSTITUT BOTANIQUE DE L'UNIVERSITÉ DE MONTRÉAL. *No. 37, Notes sur les Cistes. I. La Collection du Bailey Hortorium*, by Pierre Dansereau. *Introgression des Characteres de l'Acer saccharophorum K. Kooch et de l'Acer nigrum Michx.*, by Pierre Dansereau and Andre Lafond. *No. 38, Études sur les Hybrides de Cistes. IV. Corrélation des caractères du C. salviifolius L. VI. Introgression dans la section Ladanium*, by Pierre Dansereau. *No. 39, Studies in the Genus Heterosporium*, by J. Emile Jacques.

Institut Botanique de l'Université de Montréal, Mon-

tréal. 9 x 6. No. 37: 31; 25 cents: No. 38: 67; 25 cents: No. 39: 46 + 6 plates; 50 cents; 1941 (paper).

MORPHOLOGY

THE LYMPHATIC SYSTEM: *Its Part in Regulating Composition and Volume of Tissue Fluid. Lane Medical Lectures. Stanford University Publications, University Series, Medical Sciences, Vol. IV, No. 2.*

By Cecil Drinker. Stanford University Press, Stanford. $2.25. 10 x 7; 101; 1942.

These outstanding lectures, the 28th series in the group of Lane Medical Lectures, are destined to become classic in their field. Dr. Drinker has summarized in a clear and brilliant manner the present status of knowledge concerning the lymphatics, reviewing the trends of research which have led to the attainment of that knowledge and indicating future lines for productive study. The lectures were given under the following headings: Physiological principles displayed in the evolution of the mammalian circulation; Establishment and characteristics of the capillary circulation; Appearance and elaboration of lymphatic vessels; Blood, tissue fluid, and lymph as illustrated by experiments upon the heart and lungs; Relations of the lymphatic system to practical problems in surgery and medicine.

The essential features of the relations of blood and lymph in mammals are listed as follows:

(1) A closed system of blood capillaries with endothelial walls of varied permeability but capable of retaining practically all of the blood plasma during the usual conditions of rapid capillary transit; (2) A variable hydrostatic pressure in the capillaries; (3) A mixture of extracellular nonrespiratory proteins in the blood to which the capillary endothelium is somewhat permeable; (4) An extravascular tissue fluid, lower than the blood plasma in content of blood proteins but in other respects practically identical with plasma; (5) A system of closed lymphatic capillaries with extremely permeable endothelial walls, which lacks any inherent propulsive mechanism to move lymph into larger valved vessels but is dependent upon inconstant and extraneous forces, such as those of muscular activity or massage, to cause entrance of fluid, cells, and particles into lymphatic capillaries and eventual flow of lymph back to the blood.

Drinker emphasizes that between fish, which present the most primitive expression of these essential features, and mammals, where there is the highest complexity, no new principles are disclosed. "One finds, particularly upon the side of the lymphatics, what seems to be a straightforward increase in complexity; and this in turn must rest upon greater and greater need for the lymphatic system." He believes that the solution of the appearance and elaboration of the lymphatic circulation can best be solved by experiments on fish. Function of the lymphatics cannot be isolated from that of the blood capillaries: "Both serve the same end—the maintenance of the internal environment at constant composition and volume." In osmotic pressure of the plasma proteins, in infection, and in removal of foreign materials the lymphatics are effective, but their real usefulness "is nearly always to supplement reactions initiated in the blood capillaries and later in certain respects regulated through lymphatic absorption. They are functionally distinctive, but as part of a larger process—soldiers in an army whose individual performance may be arresting, but whose real accomplishments are inseparable from those of the army as a whole."

Introduction of microchemical methods made it possible to make repeated analyses of lymph from the same vessel. The problem of fat absorption is now capable of study since from small laboratory animals lymph and blood can be collected during periods of fat deprivation and fat feeding. It will perhaps ultimately be possible to trace the gradual steps in the development of one of the most specialized features—the villi—of the lymphatic system.

The volume is beautifully printed and illustrated. It is provided with a substantial bibliography but unfortunately there is no index. We strongly recommend this book for biological and medical school libraries.

FUNCTIONAL NEUROANATOMY.

By Wendell J. S. Krieg. The Blakiston Company, Philadelphia. $6.50. 10½ x 7¾; xx + 552; 1942.

This is a volume, comprising textbook, laboratory directions and atlas, which may profitably find its way to the desks of many students. From several points of view it is highly superior to comparable existing treatises for the beginning student. In the first place, in the case of each functional system a clear and relevant discussion of the structure and function of the peripheral nerves and sense organs is included. This, although frequently only briefly reviewed in neurology because of the student's supposed familiarity with it from gross anatomy, is extremely welcome here since the student is enabled to coordinate it intelligently with his knowledge of the related central parts. Second, the book contains lucid discussions of many functional aspects of neurology which are often available only in textbooks of physiology, but which do well to share the pages in which the related anatomy is described. Finally, a number of new and highly original illustrations are included which demonstrate vividly many points that are nowhere else in print so clearly illuminated. The figures are especially fine in the case of gross dissections and of reconstructions demonstrating topographical relationships. Some students will find helpful the three-dimensional interpretations of the atlas drawings.

Constructed according to the principles of functional systems, the work as a whole is often not tightly enough organized in detail to complete successfully the whole discussion of a system within a single unified section, and, therefore, in this respect it is less useful than some

of the texts already avaiablie. Furthermore, the treatment of actual fiber-tract connections in both text and illustration is less satisfactorily handled and is less clear than much of the other material presented. The book as a whole, therefore, serves as an excellent and desirable supplement to already existing textbooks, rather than as a substitute for them.

If a reviewer dares hazard a few suggestions to an author who states in the preface of his work that he has "satisfied himself that he cannot materially improve on it, either in content or form," the following points may be mentioned. The double use of the word *thalamus*, both as an approximate synonym for *diencephalon* and also in its normal sense to describe the thalamus proper, is sure to be confusing to beginning students. Controversial issues (e.g. macular sparing, ipsilateral motor representation in the cortex, classification and localization of speech or language mechanisms, etc.) are not always judiciously treated. Stereograms designating the planes of section are omitted only for the very portions of the atlas where the beginning student has most need of them, namely, the brain-stem anterior to the midbrain, where the sections are in a plane intermediate between transverse and frontal.

The book is magnificently printed, but there are some bad typographical errors and one tantilizing pun—*re* the "Procrustean six layers" of the cortex.

A Textbook of Histology. *Fourth Edition, Completely Revised.*

By Alexander A. Maximow and William Bloom. W. B. Saunders Company, Philadelphia and London. $7.00. 9¾ x 6⅝; xv + 695; 1942.

Reviews of the three previous editions of this book have appeared in Vol. 6, p. 242, Vol. 10, p. 110 and Vol. 14, p. 93 of this journal. Slight additions have been made in most of the chapters in order to bring the material up to date. A section on the history of histological methods has been added to the introduction and recently developed techniques are included. The section on the composition and structure of protoplasm has been rewritten by R. R. Bensley. The sections on histogenesis and repair in the chapter on bone, the sections on the aortic and carotid bodies in the chapter on the blood vascular system, and the sections on the white pulp, and the union of arteries and veins in the chapter on the spleen contain slight changes and additions, as do the sections on the thyroid, the parathyroid, the pancreas and the skin. The section on the neuron doctrine in the chapter on nervous tissue has been rewritten by S. Polyak, who has also condensed and revised the section on the retina in the chapter on the eye. In the chapter on the female genital system, the sections dealing with the endometrium of the uterus, its cycle and endocrine correlations, and in structure in early pregnancy have been extensively revised and supplemented by G. W. Bartelmez. The illustrations have been increased by 35 new figures, bringing the total number to 562. However, the majority of the changes which have been cited are of a minor nature. This comprehensive book is to be highly recommended for the use of medical and pre-medical students, and is a valuable reference for any teacher in the biological sciences.

A Text-Book of Neuro-Anatomy. *Third Edition, Thoroughly Revised.*

By Albert Kuntz. Lea and Febiger, Philadelphia. $6.00 net. 9⅛ x 5½; 518; 1942.

This new edition of one of the more popular text-books of neuro-anatomy has not undergone drastic alteration. Certain chapters, however, particularly those dealing with the diencephalon and the structure of the cerebral cortex, have been extensively revised and rewritten so as to include the newer literature dealing with these regions.

Numerous figures have been replaced by new ones, but some of the illustrations still leave much to be desired. The absence of a comprehensive, systematically arranged series of representative cross-sections is regrettable; for such a series is almost indispensable to the beginning student, who will be the chief user of this publication.

The chapter on the autonomic nervous system remains one of the outstanding features of the book. It should continue to be of great value to the student in correlating the gross and microscopic features of this important part of the nervous system.

PHYSIOLOGY AND PATHOLOGY

Memoranda on Medical Diseases in Tropical and Sub-Tropical Areas.

The War Office. Reprinted by permission of the Controller of His Britannic Majesty's Stationery Office. Chemical Publishing Company, Brooklyn. $4.75. 8½ x 5½; 282; 1942.

This is indeed a practical book for one who is concerned with tropical and sub-tropical diseases and desires a source of authoritative information. The information that is compiled has been obtained from the experiences of army medical officers who have actually encountered the diseases under war conditions. Fortunately the non-essentials have been omitted in order to make it a small book that one would not hesitate to include among his limited equipment.

As is stated in its preface, the book does not cover the whole range of tropical medicine. There are a number of relatively rare diseases which might be encountered in the tropics about which the book has nothing to

relate. Nevertheless the fact that this is the sixth edition of the *Memoranda*, indicates that it has proved to be a handy manual for use in the field. The diseases that are discussed are not limited to those produced by one or two general types of etiological agents, but the most frequently encountered tropical diseases are discussed regardless of the agents or conditions that cause them. For instance, diseases caused by infection with worms, protozoa, fungi, bacteria and filterable viruses are included along with a consideration of arthopod pests, heat-stoke and vitamin deficiencies.

The subject matter is well organized and written in an interesting style. After a brief introductory statement concerning a disease, its etiology, symptoms, complications, diagnosis, differential diagnosis, prophylaxis and treatment are presented usually in the order named. The most valuable portion of the discussion usually concerns the symptoms and the treatment of the disease. The symptoms are described fully and in vivid detail, as is possible only by those who have had frequent experience with the disease. Various types of treatment are presented; the ideal treatment where time, equipment and supplies are not problems on down to the emergency first aid that may be all that can be given during active combat.

In the appendix, the International Rules of Zoological Nomenclature are presented with the hope that they might be helpful to the medical officer in writing reports concerning animal parasites. The text is well illustrated with drawings, photographs, and reproductions of fever charts. In addition to the list of contents, an index is also included.

AMBASSADORS IN WHITE. *The Story of American Tropical Medicine.*

By Charles Morrow Wilson. Henry Holt and Company, New York. $3.50. 9¼ x 6; x + 372; 1942.

Wilson has effectively brought to the attention of the general reader what has long been known to the public health officer—the great battle yet to be fought in Latin America to combat the deadly toll of infectious diseases.

There are somewhere around a hundred and twenty million people in Latin America, from the Rio Grande to Cape Horn. At this very moment it is a good bet that at least fifty million of them are sick. Sick of everything from sprue to leprosy. Sick of almost all the diseases that we in the United States encounter in our own lives, and of a multitude of savage and highly fatal diseases about which we know almost nothing.

Tuberculosis is to-day the deadliest of tropical diseases, with influenza-pneumonia, malaria, diarrhea-enteritis, diphtheria, infantile paralysis, typhoid, and meningitis following in decreasing order. Excluding cancer, which is fifth on the list of the ten main causes of death, and heart disease, which is ninth, the eight remaining principal sources of fatality are the result of hostile organisms. "Sickness in Latin America," says Wilson, "is as much a condition of life as weather or food. Even yet we are far from understanding what fifty million sick people mean. They signify a society of sick men."

Widespread illness does not mean that our neighboring countries are not carrying on a valiant battle against disease. The problem is one of great magnitude and complexity. Large sections of the population are in the midst of vast expanses of jungle, mountain, and desert, or beyond such regions out of communication with more progressive peoples. Scarcity of communication, clinical facilities and modern equipment, lack of independent medical practitioners, illiteracy and poverty among large groups of the inhabitants coupled with racial prejudices all have a part in making the fight to eradicate disease a difficult one.

It is a stirring story that Wilson tells of the great battles that have already taken place against tropical disease and of the men—Finlay, Walter Reed, Gorgas, Deeks, Noguchi and many others—who have served in the fight, also of the work of the United Fruit Company, The Rockefeller Institution and other organized groups. His statements are supported with bibliographical notes for each chapter (grouped together at the end of the text). A general bibliography of 149 titles and a chronological list of Latin American epidemics are given in the two appendices and the volume is carefully indexed.

FAMILY FOOD CONSUMPTION AND DIETARY LEVELS. *Five Regions. U. S. Department of Agriculture, Miscellaneous Publication No. 452. Consumer Purchases Study. Urban and Village Series.*

By Hazel K. Stiebeling, Day Monroe, Esther F. Phipard, Sadye F. Adelson and Faith Clark. Government Printing Office, Washington. 30 cents. 9⅛ x 5¾; iv + 268; 1941 (paper).

Food consumption is a subject of universal and perennial interest. About half of the income of families in the lowest third of the income scale goes for food. Even those in the highest third put more than a fifth of their incomes into this item of the budget. The way food money is spent, the choices that families make, is of much concern to all interested in human welfare; there is a close relationship between dietary adequacy and health. Producers also have an interest in the volume and kind of food eaten by the population. Such facts bear directly on the activities and incomes of farmers, workers in food industries, and persons engaged in transportation and other distributive services.

The main requirements for eligibility of families for this survey were: families to include a husband and wife, both native-born; the husband and wife to have been married at least a year and to have kept house in the community studied for at least 9 months of the report

year: white families, except in the Southeast, and in New York City and Columbus, Ohio, where a separate study (included in this report) of Negroes was made; no family to have had the equivalent of more than one roomer and/or boarder for 52 weeks of the report year and no family to have received relief during that period. These requirements together with other minor requirements threw families into the study group that were generally in better circumstances than those omitted from the study. Therefore, the authors point out that the "differences between the groups studied and the total population should be recognized in using the expenditure and consumption data of this volume."

The report includes money value of food in a 12-month period, dietary patterns as shown by 7-day schedules, human requirements for nutrients as discussed in this report, nutritive value of diets in relation to money value of food, nutritive value of diets in relation to degree of urbanization and region, classification of diets by grade, etc. This part of the report covers 73 pages. The remaining 191 pages are taken up with four appendixes concerned with table titles, legends for the figures, tables, methodology and appraisal, and glossary.

ANNUAL REVIEW OF PHYSIOLOGY. *Volume IV. Edited by James M. Luck and Victor E. Hall. Annual Reviews, Inc. Stanford University, P. O., Calif.* $5.00. 8¾ x 5¾; vii + 709; 1942.

The *Annual Review of Physiology* has rightly come to fill an indispensable place in the reading of a great number of general biologists as well as physiologists. This volume is no exception. The articles are of the same general type as in previous editions, giving very brief but authoritative summaries of the current work in various active fields of physiological investigation. The majority of articles are on topics which have been covered regularly by this review and, in these, most of the works cited are limited to the period of 1940 to early 1941. Chapters on topics not recently included in this review also contain references to older research. Because of war conditions the material covered is largely by Americans, but foreign papers have been included as they have become available.

The volume contains sections on Permeability, Physiological effects of neutron rays, Physiological aspects of genetics, Developmental physiology, Water metabolism, Growth, Energy metabolism, The physiology of the skin, The peripheral circulation, Heart, Blood, The digestive system, Kidney, Electrophysiology, The spinal cord and reflex action, The central nervous system, The autonomic nervous system, Sense organs, Metabolic functions of the endocrine glands, The physiology of reproduction, Physiological psychology, Applied physiology, and The pharmacology of drug addiction.

The subjects of water metabolism and pharmacology of drug addiction appear for the first time in this *Annual* and those of permeability and applied physiology appear for the first time since 1939. The latter is quite different from the first presentation of this subject, and deals almost entirely with pressure effects as they are involved in aviation and submarine work. Military secrecy prohibits the publication of much of the recent work dealing with these problems, but the authors of this section were able to review a considerable volume of valuable work and their discussion does much to draw attention to the many problems in this field which demand immediate attention.

Each section of the book is provided with a comprehensive bibliography and there are complete author and subject indexes.

TEXTBOOK OF CLINICAL PARASITOLOGY: *Including Laboratory Identification and Technic. By David L. Belding. D. Appleton-Century Co., New York and London.* $8.50. 9⅛ x 6½; xxi + 888; 1942.

As inferred by the title, this textbook places emphasis upon the clinical aspects of parasitology. It seems to possess all the information necessary for a physician to diagnose and treat parasitic diseases successfully. In spite of this primary interest, the book also presents the zoological background of the parasites without which a more complete understanding of the diseases would be impossible. Experience has demonstrated that successful prevention and control are only possible through the application of a well-rounded knowledge of the subject. Such a knowledge can be acquired through a study of this book.

The most outstanding feature of the volume is the frequent use of charts and diagrams for presenting various types of data. For instance, they are used to graphically present life cycles, geographical distribution, pathology, symptomatology, treatment, classification, and morphology. They are not presented to take the place of descriptive text, but serve as clear, concise summaries and readily available sources of information. The student will find them a great help while endeavoring to acquire the fundamental facts. Others will find them equally helpful for refreshing their memories on subjects studied in the past.

The protozoa, helminths, and arthropods that cause human diseases are discussed in the order named. Some of the closely related parasites of lower animals are also included. The first several chapters are devoted to parasitism in general and the frequent relationships that exist between the parasite and the host. The last section of the book presents the technical methods for the diagnosis and treatment of parasitic infections. This section is well organized and should prove to be a help to one actively engaged in these phases of the subject. In addition to the bibliography, references to

the original literature are conveniently placed at the end of each chapter. Both a subject and an authors' index are included.

OUTLINES OF FOOD TECHNOLOGY.

By Harry W. von Loesecke. Reinhold Publishing Company, New York. $7.00. 9 x 6; 505; 1942.

The beginning of the modern food industry dates back to the era of Pasteur with the overthrow of the theory of spontaneous generation. Up to about 100 years ago salting, drying, and, to a much less degree, chilling were the only known methods assuring the prolonged preservation of food. Within more or less of a century what is probably the greatest industry in the world, the production, preservation, and shipping of food, has developed.

The money spent in obtaining food far exceeds that for any other purpose. The number of people gainfully employed in supplying the world with food is greater than any other occupation. The farmer raises his crops and livestock which he turns over to thousands of others to market. To convert these materials into raw food products many thousands more are employed in canning, baking, confectionery making, sugar refining, wholesale and storage warehouses, stores, hotels and restaurants. To this vast army may be added those employed in manufacturing dishes, silverware, machinery for processing foods, bottles, cans, cartons and thousands of other accessories indispensable to the food industry.

In the present volume von Loesecke has described briefly the more important processes in food production. Even with such a limitation—omitting all detailed descriptions of the preparation of the different food materials or the appraisal of nutrient values and the inclusion of only a minimum of statistical data—the volume contains an enormous amount of informative material. The usefulness of the volume is extended by the carefully prepared "suggested readings" list accompanying each chapter. The subject matter is divided as follows: tin and glass container; fruits and their products; canning of vegetables; dairy products; meat, meat products and poultry; fish and shellfish; grains and their products; edible fats and oils; sugars and starches; nuts; spices, relishes, essential oils, and extracts; beverages; confectionery, jams, jellies, preserves and certified dyes; storage and marketing of fruits and vegetables; and preservation of foods by freezing. The volume is well illustrated and indexed.

THE COMPLETE BOOK OF DIETS FOR ALL AGES INCLUDING MEDICAL DIETETIC SUGGESTIONS FOR 325 COMMON AILMENTS.

By Richard M. Field. Doubleday, Doran and Company, New York. $2.50. 8 x 5⅜; liv + 272; 1942.

The author's 25 years of successful medical practice, as well as his recent experience in formulating corrective dietary charts and serving as an authoritative adviser and consultant on matters pertaining to diet in relation to health and disease, have well qualified him for the task of preparing this comprehensive work. Although intended primarily for use by the general practitioner, the book is written clearly and simply enough to be profitably used by the intelligent layman.

Part I of the volume lists the nutritional requirements for man at various ages and suggests 8 normal diets to be followed under conditions of normal health. Listed also are 24 corrective diets suggested for the cure or treatment of some 325 common ailments. Throughout this section, the author emphasizes the fact that diet alone, without the supplemental aid of good hygiene, mental and emotional stability, and freedom from the multitude of modern worries, cannot bring miraculous cures over night. Stress is also placed on the fact that most people of our day resist any attempt on the part of the physician to tell them what they *must* and *must not* do, and that the best way for the physician to achieve the desired result is to hand them a list of suggestions.

Part II of the book deals with the recent (1941-42) trends in balanced nutrition. There is a plea for common sense in balancing meals; a complete debunking of many overrated commercial products having a direct bearing on nutrition; and some sound advice on the selection of many food products.

The work is authoritative and up-to-date, and as such, it will undoubtedly find a welcome place on the library shelves of many general practitioners as well as nutrition-conscious laymen.

SUPERIOR CHILDREN THROUGH MODERN NUTRITION. *How to Perfect the Growth and Development of Your Children from Birth to Maturity.*

By I. Newton Kugelmass. E. P. Dutton and Company, New York. $3.50. 8½ x 5½; xiv + 332; 1942.

The purpose of this book is to help parents perfect the growth and development of their infants and children. It grew out of the application of the newer knowledge of nutrition in the pediatric practice of the author. One of the outstanding features of the volume is the recognition that no two children are alike—that all children do not respond with equal benefit to a "well-balanced diet for the average child." The author takes into consideration the body-build, age and mental attitude of the child so that parents can pick out the proper combinations and prepare the kind of meals that will be consumed with utmost benefit for physical and mental growth to maturity. The following subjects are discussed: modern materials of life, energy and vitamin foods, minerals as protective foods, nutrition for superior growth, individualized newborn, breast and artificial

feeding, mixed feeding, food allergy, feeding behavior, dietary needs of every age, feeding according to body build, preventing constipation, safeguards for economical living, helping lean and fat children, and vitamin values of common foods. A helpful feature of the book is the "questions and answers" which are appended to most of the chapters. Complete tables of vitamins and minerals are included with instructions as to how much of each should be given and in what form each is most effective. Even the costs of these health-builders are considered in the author's recommendations.

This excellent book is recommended to parents and to school, camp, hospital, Red Cross, and day-nursery officials who may not have the time or the opportunity to study the technical aspects of nutrition. It should be widely accepted.

MODERN MEDICINE: *Its Progress and Opportunities.* *Netta W. Wilson and S. A. Weisman. George W. Stewart, Publisher, New York.* $2.00. 8 x 5¾; vi + 218; 1942.

This is the sort of book which this reviewer believes should be in every family library for it contains the authoritative information that all intelligent and well-informed laymen like to have about the important aspects of modern medicine. The main ideas, the great discoveries, the cures, and the personalities that have advanced the practice of medicine all are recounted here. The chief problems that modern medicine is trying to solve, other problems that have been solved in the past, the most recent developments in medical theory and practice, and the opportunities for careers that should especially interest young men and women are all discussed completely by the authors. The stories of bacteria, virus diseases, animal parasites of man, vaccines and serums, animal experimentation, the heart and some of its diseases, the blood and some of its diseases, tuberculosis, cancer, surgery, anaesthesia, the endocrine glands, and nutrition are all told in succession in a most entertaining and instructive manner. The book concludes with a chapter on "Modern medicine looks forward." Appended to the volume are a comprehensive list of books to read about modern medicine and a complete index.

This book is heartily recommended to all those adults, young and old, who have a normal interest in science and in the world about them but who know nothing technical or detailed about human physiology and the intricacies of modern medical practice.

RABIES.

By Leslie T. Webster. The Macmillan Company, New York. $1.75. 8 x 5¼; vi + 168; 1942.

With rabies becoming more and more a community problem the public is demanding information on two cardinal points: how rabies is diagnosed and how rabies can be controlled. The author feels that there is definite need for some treatise on rabies, critical, fairly inclusive, but simple and available to all. This book is an attempt to fill that need. Since the questions of diagnosis and prevention seem uppermost in the minds of most inquirers the author focuses the subject matter on these two problems. Quantitative data and present concepts are stressed rather than original observations and the chronological development of ideas. In addition to a long-needed survey of the available literature on rabies, the author gives a detailed report of the Rockefeller Institute's "mouse tests" for diagnosis and for evaluating rabies vaccines. The discussion includes: rabies in animals and in man, the cause, diagnosis, history and epidemiology of rabies, and the prevention of rabies prior to and following exposure. There is a complete bibliography and a comprehensive index provided. The appendix contains information relative to the disposal of rabid and of vicious dogs, confining animals to prevent spread of the disease, rabies antibodies and their relation to immunity, and immunizing potency of antirabies vaccines.

This volume will prove useful to the dog owner and general public, and indispensable to those engaged in rabies research, to doctors and veterinarians, and to public health administrators.

INTIMATE BACTERIOLOGY: *A Text and Laboratory Manual.*

By Casper I. Nelson. Burgess Publishing Company, Minneapolis. $2.50. 10½ x 8½; v + 166; 1942.

Designed for use in the teaching of continuation classes in general bacteriology, the plan of this combination text and laboratory manual is to present the relationship of bacteria to the human body from the very beginning of the individual's existence to old age and death. This it does in a very commendable and novel fashion. Some of the more interesting chapter headings have to do with: prenatal infections, bacterial flora of the intestinal tract, weaning, constipation, use and abuse of cathartics, correction of health through diet, food poisoning, public sanitary services, the disposal of sewage and its relationship to public health, the respiratory tract, children's diseases, the skin and hair, and immunity and allergy. In the section of the book devoted to laboratory exercises, complete descriptions and directions are provided for a semester's work in the laboratory—with many of the standard exercises available along with a number of interesting new ones. References are given as footnotes throughout the book. There is no index. The book is illustrated with a number of drawings.

The volume is recommended for that group of students who, having been intrigued by a general course in

microbiology, would like to learn just a little more with special regard to self-application, but do not necessarily wish to follow into the field of medicine. For them, this method of presentation should hold their interest in a natural and effective way.

THE CONQUEST OF BACTERIA *from Salvarsan to Sulphapyridine.*

By F. Sherwood Taylor. Foreword by Henry E. Sigerist. Philosophical Library and Alliance Book Corporation, New York. $2.00 8¾ x 5⅝; 178; 1942.

This book, written by one of England's most eminent scientists, is the story of the chemical discoveries which conquered disease, and of the men behind these conquests. The appeal of the volume is quite definitely to the layman who is interested in reading a fascinating study of a subject heretofore reserved mainly for the specialist. The author discusses in order: bacteria and disease, the body's defenses, the development of drugs, the rise of chemotherapy, prontosil, the sulphonamide group of drugs, sulphonamides and Streptococcus pyogenes, pneumonia and M and B 693, further triumphs—including limitations of treatment and mode of action—and, finally, the need for continued research, including material on the present expenditure of public money on health services and on research, the present state of research, and the work of the various pharmaceutical firms in relation to chemotherapeutic research. There is no bibliography, but a comprehensive index is available. There is also a table of the various sulphonamide drugs.

Many readers will find this the best type of popular book on a scientific subject, and it should be warmly received by the thousands of people who have read accounts of the new miracle drugs and who would like to know the latest developments concerning them, as well as something about their interesting history.

THE 1941 YEAR BOOK OF GENERAL MEDICINE.

Edited by George F. Dick, J. Burns Amberson, George R. Minot, William B. Castle, William D. Stroud and George B. Eusterman. The Year Book Publishers, Chicago. $3.00. 7 x 4¾; 848; 1941.

The merits of this group of the well-known "Year Book Series" are sufficiently wide-spread to obviate the necessity of saying much about the book. The subject matter is divided into five sections: infectious diseases, diseases of the chest, of the blood and blood-forming organs, of the heart and blood vessels, and of the digestive system. The distinguished editors of the volume have examined the voluminous literature in the above-mentioned five fields of general medicine and have selected the more important and more promising articles which are here collected and published in one volume of 850 pages for the reference use of the general practitioner, the medical student, and the seasoned investigator, to all of whom this book should prove indispensable. Here are recorded the latest developments in: sulfonamide therapy, pneumonia, tuberculosis, pneumoconiosis, anemias, nephritis, electrocardiography, diabetes, vitamin nutrition, hemophilia, hypertension and poliomyelitis—to mention only a few of the subjects considered. The book is illustrated with numerous photographs, drawings, charts, tables and graphs, and there is a complete index of the subject-matter, as well as an index to the authors represented.

INTRODUCTION OF HUMAN PHYSIOLOGY. *Third Edition, Revised.*

By Lathan A. Crandall. W. B. Saunders Company, Philadelphia and London. $2.25. 7¾ x 5⅛; xii + 388; 1942.

This little volume is recommended for introductory courses in physiology for college students and nurses. The most essential phases of the vast modern science of physiology have been selected and presented in the simplest possible fashion with often more attention to the practical than to the theoretical aspects of the subject matter.

The book was first written in 1934. For this third edition the author has added a new chapter on nutrition and has extensively revised the sections dealing with metabolism, the function of capillaries, etc. In order to be up-to-date he also gives considerable space to a discussion of the problems of respiration in relation to high altitude flying. Most of the 113 illustrations are well chosen and very helpful to the reader, but some are not clearly reproduced or else too much reduced in size.

There is a good glossary, an adequate index and a very brief list of references for additional reading. Precisely because this book is intended for beginners, a chapter outlining the historical development of physiology would have been desirable at least to indicate that we are still in the midst of rapid advances in the full understanding of the real functions of our bodily structures and their manifold interrelations.

THE PHYSIOLOGY OF DOMESTIC ANIMALS: *with a Chapter on The Physico-Chemical Basis of Physiological Phenomena, by E. A. Hewitt: A Part on the Endocrine Organs and Reproduction, revised by S. A. Asdell. Fifth Edition, Revised.*

By H. H. Dukes. Foreword by H. D. Bergman. Comstock Publishing Company, Ithaca. $6.00. 9 x 6; xiv + 721; 1942.

The present edition, the fifth since the volume first appeared in 1932, has been revised and much of it completely rewritten. A number of subjects have been

added, such as a chapter on digestion in the chicken, sections of respiration in birds, urine of the chicken, reproduction in the fowl, and physiological oxidations. The material on the endocrine organs has been merged with the part on reproduction under the heading "The endocrine organs and reproduction." Much of the anatomical material in the part on the nervous system has been deleted in the present edition and many changes have been made in the illustrations.

Originally designed for students of veterinary medicine, with the extensive revision and up-to-date presentation of the subject, the usefulness of the volume extends to workers in animal husbandry and practitioners of veterinary medicine. The volume will also be found invaluable in those biological laboratories where there is much experimental work with animals.

FOOD VALUES IN SHARES AND WEIGHTS.

By Clara Mae Taylor. The Macmillan Company, New York. $1.50. 9⅔ x 7; 92; 1942.

Out of the recent nutrition-consciousness of America has arisen the need for just such a handbook as the one under review. For the layman who wants to know the relative values of various foods as regards their nutritional components, as well as the minimal nutritional requirements for normal health and vitality, this book will undoubtedly prove to be both valuable and popular.

After a brief discussion of the minimal daily nutritional requirements of the human body in terms of calories, proteins, calcium, iron, vitamin A, thiamin, ascorbic acid, and riboflavin, (30 shares of each are designated as the daily requirement for a moderately active man) the work lists, in Table II, some 500 dietary items showing the number of shares derived from a given quantity of food, and in Table IV, the same dietary items giving the food values in weights. There is a brief graphic presentation of the comparative nutritive value of several foods. Space is provided for recording calculations of food intake for one day in terms of shares, weights, and menus.

The work carries a bibliography of 15 titles.

THE 1941 YEAR BOOK OF PUBLIC HEALTH.

Edited by J. C. Geiger. The Year Book Publishers, Chicago. $3.00. 7 x 4⅛; 544; 1942.

Under the following headings Geiger has grouped the summarized material which he has selected from a large number of journals as being outstanding for the year and of greatest usefulness to his readers: medical care, child hygiene, communicable diseases and epidemiology (4 divisions), dental hygiene, food and milk, health education, hospital hygiene, housing, industrial hygiene, laboratory, maternal care, mental hygiene, military hygiene, nursing, nutrition, and statistical.

Many of the articles are accompanied by brief editorial notes (in small type), and in some instances figures and tables have been included. There is a general index and one of authors. A handy volume which will well serve the busy public health worker as well as others interested in contemporary public health developments.

BIOCHEMISTRY

A SYMPOSIUM ON RESPIRATORY ENZYMES.

By Eric G. Ball, Fritz Lipmann, Kurt G. Stern, Fritz Schlenk, et al. University of Wisconsin Press, Madison. $3.00. 9¼ x 6; xii + 281; 1942.

The extremely rapid advances which have been made in our knowledge of enzymes and their action during the past few years have made it practically impossible for most biologists to keep up with the voluminous literature on this subject. However, a knowledge of enzyme chemistry is increasingly important in interpreting and evaluating other biological data. Reviews of the nature of this symposium are therefore extremely valuable to the general biologist as well as to the enzyme specialist.

This book represents a compilation of the most recent facts and theories dealing with the particularly important enzymes of respiration and intermediary metabolism by 27 contributors including many of the most active American investigators in the field. The Foreword states that the symposium was primarily designed to discuss the interrelations of vitamins and enzymes, but respiratory enzymes not directly correlated with vitamin action are also included. This is necessary to give a well-rounded picture of the subject, as it would be impossible to consider the pyridine nucleotides or flavoproteins as systems isolated from respiration in general.

The contributors include theory and speculation as well as established fact in their papers and differences of opinion on such issues as the citric acid cycle and the "by-passing" of the cytochrome system present points of view to be evaluated by the reader. The considerable emphasis placed on the unsolved problems in the field gives the book added value to those who are actively interested in the problems of respiration.

Each article is accompanied by a good bibliography. In view of the tremendous volume of literature on this subject, these can hardly claim to be complete, but they do represent the most pertinent articles and provide a suitable starting point for anyone wishing to investigate a particular problem more thoroughly. There is no index, but the very complete table of contents makes the material readily available for reference.

There can be little question but that this book will adequately fill the need for a concise and authoritative review of our present knowledge concerning respiratory enzymes in both normal and pathological tissues. It should be of value both to the biochemist and to the

general biologist striving to keep abreast of this rapidly expanding field.

FROM WITCHCRAFT TO CHEMOTHERAPY. *The Linacre Lecture 1941.*

By Sir Walter Langdon-Brown. Cambridge, at the University Press. 60 cents. 7¼ x 4⅞; 60; 1941 (paper).

To comprehend witchcraft Langdon-Brown says that "we must see it as an expression of the thwarted instinctive self turned renegade and forcing its way into consciousness again with an evil leer. Witchcraft and fertility rites had seized on the imagination of people thousands of years before the introduction of Christianity." Witchcraft he conceives to be "the persistent vestige of the old fertility religion." It is estimated that throughout Europe, within the space of 100 years, something like two million persons were burned as witches. That in the 17th century such persons as Sir Thomas Browne, Henry More, and Joseph Glanvill believed in witches was due probably to the fact that to doubt the existence of evil spirits implied an equal doubt in the existence of beneficent spiritual forces.

The widespread use of drugs and poisons in the magic rituals led empirically to the discovery of the therapeutic value of many of these. It is estimated that 137 modern botanical remedies undoubtedly emanated from folk-medicine, and that 25 probably and 17 possibly did. The author lists briefly the supposed characteristics and virtues of the following: mandrake, poppy, aconite from monkshood, and conium from hemlock, cinchona and mistletoe, wormwood, chamomile, scurvey grass, digitalis, and valerian. It was not until the end of the 18th century with the revolution in chemistry that pharmacology could properly evaluate these and similar herbs and drugs. But the great change was not to come until a century later with the discovery of endocrines, antitoxins, vitamins, and X-rays and radium, all within a comparatively brief period. Then began the era of chemotherapy "the last great triumph of therapeutics."

A SIMPLIFIED SYSTEM OF ORGANIC IDENTIFICATION.

By J. L. B. Smith. Chemical Publishing Company, Brooklyn. $1.50. 8½ x 5½; 48; 1942.

The scheme presented in this workbook uses to the utmost the simple, practical, and time-saving taste, odor, color, and reaction tests in identifying a large number of organic compounds, and is completely devoid of the theoretical principles and detailed formulae inherent in most organic texts. The work is set up in the form of a key, using generally a binomial system to describe progressive reactions; e.g. "neutral or only faintly acid vs. distinctly acid"; "immediate pink color vs. no bright pink color"; "insoluble vs. soluble"; etc.

Except for the alkaloids and dyestuffs, the manual covers a range of material (some 250 individual compounds) which more than meets the requirements for the A.B. degree, and with suitable selection and eliminations, can be adapted to meet the needs of many college class levels. The value of this revolutionary method of presentation is attested by the success with which it has been employed by the author for a number of years in his classes at Rhodes University College, Grahamstown, South Africa.

An appendix listing the composition and strength of a number of reagent solutions, and a complete index are provided.

BIBLIOGRAPHY OF REFERENCES TO THE LITERATURE ON THE MINOR ELEMENTS AND THEIR RELATION TO ANIMAL NUTRITION. *Third Supplement to the Third Edition.*

Originally compiled by L. G. Willis. Chilean Nitrate Educational Bureau, New York. Free. 11 x 8½; 78; 1942 (paper).

SEX

SEX GUIDANCE IN FAMILY LIFE EDUCATION. *A Handbook for the Schools.*

By Frances Bruce Strain. The Macmillan Company, New York. $2.25. 8 x 5¾; viii + 340; 1942.

Mrs. Strain's wide experience in sex education has well fitted her to write the present book. It is designed for the use of the teacher. The author emphasizes the need for a long range program in sex education in schools through all the grades from primary to junior and senior high schools. That there is need for such a program, especially during the present conditions of war with the accompanying disorganization of homelife there seems little doubt. There is far more in sex teaching than the simple facts of mating, fertilization, and birth of human beings, as Mrs. Strain clearly shows. Many of these divergent problems can be more naturally dealt with in the school than in the house, but sex education should really be "a matter of cooperation between home and school, each doing its part."

It is recommended that the terms and phrases which belong to past thinking be abandoned.

There is the king-word itself, 'Sex', weighted with all the bias and calumny of centuries .... Yet how difficult it is to replace.

In the upper grades where the program has crystallized into a definite entity, a name for the study would give significance and prestige. 'Human Relationships,' 'Family Living,' 'Preparation for Marriage' are all appropriate for a year's or a semester's course of study.

Sex Guidance is the chronicle of the unfolding of a child's sexual nature from the first days of his entrance

into school to the last before graduation. In the observation of this unfolding, a teacher will come to find many of the partitions and boundaries in her mind shifting or disappearing altogether. She will find that much conduct which appears to be sexual is social, and much that is social is sexual, that affection often wears the mask of cruelty, and cruelty the mask of affection. The sex education student today will need to be not only a biologist but a psychologist. He must be as much concerned with the dynamics of social and emotional growth as with reproduction, as skilled in interpretation of conduct as of chromosomes and the Mendelian Law.

We strongly recommend this book to all teachers whether it is their lot to take part in a program for sex education or not. It carries much wisdom and sensible advice for which all who have to do with young people will be grateful.

MICE, MEN, AND ELEPHANTS; *A Book about the Mammals.*

By Herbert S. Zim. Illustrated with Drawings by James Macdonald and with Photographs. Harcourt, Brace and Company, New York. $2.00. 8¾ x 5⅝; 213; 1942.

The problem of instruction in sex and its allied fields is probably one of the most difficult tasks in secondary education and the techniques of presenting this information are indeed numerous and varied. In this very simply written little book about the mammals the author, a teacher of science, has endeavored to answer the questions which he has found from his own experience uppermost in the minds of several thousands of his pupils—questions about themselves and other animals. Instead of giving isolated answers he has tried to fit them into their place in the general scheme of things. For example, he leads up to the principal facts about reproduction in man by first describing the general plan followed by all mammals from the smallest to the largest, and then points out the differences in the details of this plan found among the various types of mammals, including man.

"When you know more about your relatives, the mammals, and how they live, you will understand more about yourself—about the parts of your own body, what they are for, and how they work."

The book is illustrated with photographs and drawings.

BIOMETRY

ANNUAL BULLETIN OF VITAL STATISTICS FOR THE YEAR 1940. *Including Summary Vital Statistics for 1921–1940.*

State of Tennessee Department of Public Health. Nashville, Tennessee. 11 x 8½; 80; 1942 (paper).

In this bulletin are presented a summary of the vital statistics data for the year 1940 in relation to the data for previous years, summary tables with the data for the state for the 20 years, 1921–1940 inclusive, and detailed data for 1940 for the state, urban and rural areas, for the twelve cities with populations of 10,000 or more, and for the ninety-five counties in the state. The causes of death have been classified under the title numbers of the *1938 Revision of the Manual of the International List of Causes of Death* used with the *Manual of Joint Causes of Death.* In the presentation of the data both recorded and resident data are shown. For the first time in 1940, a secondary or first contributory cause of death has been tabulated in addition to the usual primary cause. The present *Bulletin* contains five complete tables, giving information relative to: population, births, stillbirths, deaths, infant deaths, and maternal deaths—with rates. The principal causes of death in 1940 have been studied for five adult age groups with somewhat surprising results in the younger age groups. There is no index provided.

RESIDENT VITAL STATISTICS OF CITIES AND COUNTIES —NEW YORK STATE 1930–1939. *Births, Stillbirths, Infant Mortality, Deaths from Important Causes, and Cases of Certain Reportable Diseases.*

New York State Department of Health. Albany, N. Y. 9 x 5¾; 135 + 3 maps. 1942 (paper).

The tables in this report show the basic vital statistics of New York State, New York City, and the rest of the State subdivided by counties, and places over 10,000 population in each of the years 1930–1939, and in the two five-year periods 1930–1934 and 1935–1939. The estimates of population are based on the federal censuses of 1930 and 1940. The statistics for areas in which state or federal institutions are located are exclusive of these institutions. All births have been allocated according to the usual place of residence of the mother. Cases and deaths from communicable diseases have been allocated to the place of origin of disease, and deaths from all other causes have been allocated to the usual place of residence. The rates for 1930–1034 and 1935–1939 are based not on annual averages but on the combined population and the total number of births and deaths for each of the five-year periods. In addition to the tabular material, certain data are included in pictorial form. There is no index provided.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 4, Number 4, December 1942.*

Edited by N. Rashevsky. University of Chicago Press, Chicago.

This number contains the following papers: An analysis of the shapes of a cell during division with particular

reference to the rôle of surface tension, by H. D. Landahl; Equilibrium shapes in non-uniform fields of concentration, by H. D. Landahl; Cellular forms: The tri-axial cell, by Alston S. Householder; The linear theory of neuron networks: The static problem, by Walter Pitts; Some problems in mathematical biophysics of visual perception and aesthetics, by N. Rashevsky.

PSYCHOLOGY AND BEHAVIOR

SENSATION AND PERCEPTION IN THE HISTORY OF EXPERIMENTAL PSYCHOLOGY.

By Edwin G. Boring. D. Appleton-Century Company, New York and London. $5.00. 8¾ x 5¾; xv + 644; 1942.

This important book is a part of a larger plan. In 1924 the author had resolved to write a history of experimental psychology which should include an introductory account of the principal men and schools, to be followed by the main historical discussion of development in the various traditional fields of psychology. By 1929, however, the introduction on men and schools had become a sizable book in itself and this admirable work was then published under the title of *A History of Experimental Psychology*. By 1942, and in a somewhat similar fashion, the treatment of the vast literature in the traditional fields of sensation and perception became the present book. A third book may be written later on; this would present the experimental history of the remaining fields including emotion, learning, thinking, action, and attention.

The author writes that his histories are not historian's histories. "In both I have written solely to show how psychology came to be as it is now." This means that events which were outstanding in the past but not effective in shaping the present get little consideration. For instance, Weber's law and the nativism-empiricism controversy had both loomed large in the nineteenth century but they loom small today and in this book.

The first chapter deals, in historical perspective, with the general nature of sensation and perception, while the second is concerned with the physiology of sensation. There follow six long chapters devoted to visual matters and next come three substantial chapters on audition. These visual and auditory sections together comprise over one-half of the entire volume. Then follow the briefer treatments of the other sense fields. The next to the last chapter tells of the perception of time and motion while the final chapter is a brief and general analysis of the nature of scientific progress in relation to human thinking.

It is not surprising that the author was keenly alive to the difficulties and the responsibilities of his tasks of selection and presentation. He understood so well "how a mood that determined the choice of an afternoon's exposition can fix the 'truth' of a certain matter upon graduate students for years to come." It was clear to him how personal interests or specialties tend to obtrude themselves unduly. He went to the original sources often to avoid the bias of rewritings. He used his guiding principle to write "solely to show how psychology came to be as it is now."

Unfortunately, Boring is not able to show just how or what psychology is now. He is powerfully motivated to do a good job, and it was for that very reason, perhaps, that caution caused him to revert to the tactic of 1929. At that time he wrote "a spindle-shaped history," one which deals with the half-century, 1860–1910, plus preceding developments and consequences. The more distant past was "tapered" and he felt unsafe about saying much regarding psychology since 1910. Exceptions were made in case of *Gestalt* psychology and behaviorism "because of the light that each casts backward upon the past." In the present volume the author seems satisfied up to 1920 at which time he starts to taper off or slow down. He stops at 1930, but again there are certain exceptions, this time most notable in the realm of audition.

We can understand the lack of perspective and the confusion of recency; the reluctance to crystallize in writing what still seems fluid. But in the case of this book on two of the most broadly important categories of psychology, much is lost by not carrying the exposition down to date. Recent material could have been duly qualified and subject to later revision, but it could have been as valuable and worthy as the recent reviews of special topics.

The content of this history is not limited on the side of recency alone. When the earlier work was written, the term experimental psychology meant "the generalized, human, normal, adult mind as revealed in the psychological laboratory." This meaning has been retained substantially in the present work, and the obvious result is a lack of much material in animal, abnormal, and child psychology—material which psychologists today call experimental. There is, to be sure, a limit to every literary effort, and this author has been conscientiously explicit regarding the limits of what has turned out to be a very fine book.

Each chapter ends with several pages of scholarly notes which not only add to the value of the text but also may serve as points of departure for further reading. There is a detailed index of subjects as well as an index of authors. The text is illustrated with 96 figures.

POETRY AND PROPHECY.

By N. Kershaw Chadwick. Cambridge, at the University Press; The Macmillan Company, New York. $1.75. 7¾ x 4¾; xvi + 110; 1942.

The greatest cleavage plane in the human species is not

that between capital and labor, or that between the white and yellow races, or that between militarism and pacifism, for these antitheses, while they may disapprove of each other, can at least understand each other. Often the capitalist began life as a laborer, and almost always the laborer has ambitions to become a capitalist. But between the general run of the population and those chosen few who have mystic experiences there is a great gulf fixed.

Within recent years there has been a renaissance of interest in mysticism. This is natural in view of the failure of those who consider themselves hardheaded practical men to make democracy safe for the world. The multitudes in the Vale of Decision have lost confidence in their leaders, and are lifting their eyes to the mountains for help. Under these circumstances it is not surprising that fake prophets have arisen and continue to arise, proclaiming divers and strange teachings, who claim access to ultimate reality by means other than the senses recognized by science. Probably there is no subject about which more egregious nonsense has been written, or which has been more deeply infested with charlatans, than mysticism.

But we cannot lightly dismiss *all* mystic phenomena as spurious. The well authenticated achievements in science of Emmanuel Swedenborg preclude the possibility of his having been mentally defective, and the works of Santa Teresa are not what we should expect from an imposter. Rather do they testify of her faith and remind us that "by their fruits shall ye know them."

Therefore an impartial, dispassionate scientific investigation of mystic phenomena seems urgent. But such would be attended with difficulty. One authority rather discourages the undertaking on the ground that the scientific method can apprehend no new truth, and that consequently another method is needed which can penetrate beyond the bounds of the proper field of scientific activity. Such a pessimistic appraisal of the capacity of the scientifically trained mind is fortunately not shared by the author of the book now under consideration.

Realizing that all scientific research must begin with facts, and that in this case sufficient facts are not available, the author has combed the written and the unwritten literature of the primitive peoples of three continents, making no assumptions, drawing no conclusions, but always laying foundations for further work. She finds no grounds for the popular belief that the shamans or medicine men of primitive cultures were mentally or physically unstable; on the other hand they are generally superior both mentally and culturally to the communities from which they come.

It is interesting to note that the word "mysticism" does not occur in the treatise. Yet the reader is likely to learn from this book more about the factors that produce mystic experiences than from many larger and more pretentious works which the reviewer might mention, and he hopes further works will issue from the author's pen. After all, though mystic states may be essentially esoteric, there is no reason why knowledge about them should be.

THE VARIETIES OF TEMPERAMENT; *A Psychology of Constitutional Differences.*

By W. H. Sheldon, with the collaboration of S. S. Stevens. Harper and Brothers, New York. $4.50. 9¼ x 6; x + 520; 1942.

This is the second volume of a projected series of studies of constitution, the first one, *The Varieties of Human Physique,* appearing in 1940. The authors by statistical methods arrived at "three original clusters of traits" which were expanded to twenty traits each, the three groupings coming to represent polar mental constitutions and designated viscerotonia, somatotonia, and cerebrotonia respectively. Classical examples of these interesting types of temperament are measured on a quantitative 7 point scale, so that, for example, an extreme viscerotonic individual would have a rating of 7–0–0; in like manner an extreme somatotonic of 0–7–0, and a cerebrotonic 0–0–7. The basic data rests upon examinations, carried over several years, of 200 individuals, and whether by coincidence or because of more or less subconscious bias the three contrasting temperaments finally turn out to have some relationship to the somatotypes described in the first volume and referred to as endomorphy, mesomorphy, and ectomorphy.

From the standpoint of clinical psychiatry, it cannot be said that this book offers any material which has not already been in general use in psychiatric circles beginning with the work of Kretschmer. It rests on sounder statistical basis. The authors' description of the sixty traits included under the three headings is excellent. They discuss the possibility of constitutional change without coming to any definite answer, but express the opinion that the manner of expression of a temperament can be modified, hinting that this is the purpose of "civilization."

Lest the charge be raised that constitutional psychology is a fatalistic thing, the authors state:

> The aim is to develop every individual according to the best potentialities of his own nature, while protecting him from the fatal frustration of a false persona and false ambitions. This is not fatalism, but naturalism. Its end result is to increase, not decrease the individual's opportunities for accomplished living.

PSYCHIATRY IN MEDICAL EDUCATION.

By Franklin G. Ebaugh and Charles A. Rymer. The Commonwealth Fund, New York; Oxford University Press, London. $3.50. 9¼ x 6¼; xxiv + 619; 1942.

This book is the result of a survey made by the authors

to obtain a "factual picture in the United States of psychiatric teaching and of its progress, especially during the last decade." It attempts "to give an unbiased view of the present situation with regard to the content of the curriculum, the method of teaching, and the general status of psychiatric education." The completed volume represents an enormous amount of labor in the assembling of the data and painstaking care in bringing the work to fruition. Much of the material was furnished by a survey made in 1931–1932 of the psychiatric teaching in 66 medical schools in the United States and two in Canada. Additional data from questionnaires, reports, articles, letters, personal communications and conferences have rounded out the report.

The chief value of the volume, aside from the general picture which it presents of the growing recognition of the importance of psychiatry in the teaching and practice of medicine, is its usefulness as a reference work for deans of medical schools and heads of departments of psychiatry. It furnishes information not only on the types of courses in psychiatry and method of presentation but on the teaching activities in psychiatric hospitals and the opportunities for postgraduate work in different institutions. Undoubtedly it will stimulate many of those schools that are lagging in their program in this field and it will also act as a check where enthusiasm has led to over-development along certain unproductive lines.

In a Foreword, Adolph Meyer says:

> Dr. Ebaugh and Dr. Rymer offer a synthetic as wel as regional accounting with a real integration of the programs influencing not only the specific departments of psychiatry but the permeation of the entire medical training with the most significant advance of twentieth-century medical training—the consideration and collaboration of the person of the patient and the social setting, and the penetration and coordination of the specialties which at times seem to threaten the perspective of the technical developments. The entire trend of medicine calls for a degree of mutual understanding between the branches of medicine of the patient as person, for collaboration of the physician in a program of health, and for the intensive study of the specific factors in the public and individual needs of treatment.

THE USE OF PERSONAL DOCUMENTS IN PSYCHOLOGICAL SCIENCE. *Prepared for the Committee on Appraisal of Research. Bulletin 49.*

By Gordon W. Allport. Social Science Research Council, New York. $1.50. 9 x 6; xix + 210; 1942 (paper).

The materials of this excellent monograph are organized around three central topics, namely: (1) The use of personal documents; (2) The forms of personal documents; and (3) The value of personal documents in psychological research.

Under the first topic, the author has discussed the attitude of various eminent psychologists and psychiatrists in the development of the trend of recognizing the importance of personal documents in psychological research. The list of purposes in which such material has been profitably used covers such a wide range of theoretical, practical, historical, and methodological interests that the field is certain to develop rapidly with sustained study and continued improvement.

The values, as well as the dangers encountered in the use of each of the various forms of personal documents (autobiographies, questionnaires, verbatim recordings, diaries, letters, and personal expressions in the form of literature, art, music, etc.) are discussed under the second heading, and the need for further research is emphasized.

A critical evaluation of the use of personal documents in psychological research makes up the third and last section of the work. The case both for and against the use of personal documents is strongly argued in an attempt to reach a common sense, middle-of-the-road attitude which will be conducive to critical, yet careful and sympathetic work.

In conclusion, the author makes a plea for more bold and radical experimentation with personal documents; lists the pitfalls of which the workers in the field must continuously be aware; and suggests strong counter measures against the theorists who hold that personal documents are of little or no value in psychological research.

The work is well documented, listing a bibliography of some 200 titles, and carries indices of names as well as subjects.

PERSONALITY AND MENTAL ILLNESS. *An Essay in Psychiatric Diagnosis.*

By John Bowlby. Emerson Books, New York. $2.75. 8 x 5⅛; viii + 280; 1942.

Bowlby's purpose in presenting his work in a somewhat incomplete state is in "the hope that it may stimulate others to undertake the research necessary to confirm or to modify my conclusions." His observations "confirm in principle a certain theory of typology, dispose of many common beliefs and suggest a new basis for the classification of the psycho-neuroses. . . . An attempt has been made to review all the clinical material published in English, to collate it and to compare it with new observations." The "gradation theory" is accepted by the author. No attempt is made "to discover hard and fast lines dividing healthy personalities which we meet with daily in our ordinary lives, personalities stricken with neurotic symptoms and those people whose personalities have been completely deranged, whether temporarily or permanently, by psychotic changes, because it is believed that no lines exist." The author holds that a knowledge of the *total personality* traits furnishes a more satisfactory method

for classification and diagnosis than an appraisal on particular symptoms.

The method of presentation of the material is as follows: (1) An examination of the work which has already been done in studying personality and relating it to neurosis and psychosis; (2) a schedule of personality traits which the author regards as significant in distinguishing the major types of personality; (3) tabulation of these traits for 36 patients who have suffered from a psychosis; (4) isolation of 33 traits which are believed to have special significance for diagnostic purposes; (5) description of certain personalities which are regarded as typical of certain groups of unstable personalities; (6) tabulation of the traits for another 29 patients suffering from neurotic symptoms; (7) tentative conclusions as to the relationships of certain personality types to neurotic and psychotic syndromes and suggestions of some revision of the present grouping of the neuroses.

This is a stimulating and thought-provoking book. It contains much clinical material that will be useful to the psychologist. In two appendices are given (a) the specificity of 33 schizoid traits and (b) 72 nonspecific traits. There is a bibliography of 79 titles and a useful working index.

COMPANION DOG TRAINING: *A Practical Manual on Systematic Obedience; Dog Training in Word and Picture. By Hans Tossutti. Orange Judd Publishing Company, New York.* $2.00. 7¾ x 5¼; 226; 1942.

The author of this book does not advocate that the extension of one of the rules of our public school system, namely the compulsory training of children up to a certain age, be applied to dogs, but those who read his book understandingly, or, indeed, those who are aware of the fine results obtainable in careful dog training, can appreciate what a rule of this kind would mean—not only to dog owners and their neighbors but to the animals themselves. Perhaps it will be in this direction that the S.P.C.A. will next bend its efforts!

Tossutti has had wide experience in dog training both in Europe and in this country. He emphasizes the importance *of knowing how to teach individuals how to train dogs.* Not all dogs are equally satisfactory for training: some breeds are better fitted, temperamentally, than others, yet all dogs, if carefully and sympathetically handled will yield to some kind of schooling.

The first five chapters of the present book serve to give the reader a general viewpoint concerning the psychology of dog training, equipment needed, praise and punishment, puppy education, and obedience. Then follow 12 lessons, each one dealing in detail with some one phase in schooling. The last seven chapters deal with more advanced work such as obedience tests, trailing or tracking, and correction of bad habits. Many illustrations are included in the text and the volume is provided with a brief but comprehensive index.

The volume will be especially welcomed by those dog owners who are so situated that they are unable to attend the training classes which are being established in increasing numbers in the larger towns and cities in this country.

CONTRIBUTIONS TO A PSYCHOLOGY OF BLINDNESS. *By Samuel Perkins Hayes. American Foundation for the Blind, New York.* $2.50. 9¼ x 6½; viii + 296; 1941.

This is a comprehensive treatise on the problems in the psychology of blindness, disposing of the fiction of the vicariate sensory compensation, and an excellent résumé of the thought and experimental work on "facial vision" or the sense of obstacles, which seems finally to be the result preeminently of auditory discrimination and to a lesser extent perhaps of tactual perceptions. Blind children are shown not to have any superior memory, and the presence of superiority is related to a special interest in the subject matter. There is also evidence that schools for the blind are not getting poorer mental material than was the case before blindness from birth infection was sharply reduced.

The second part of the book has to do with the adaptation of test materials for use among the blind in the study of special psychological assets. One gets from this review a hint of very serious difficulties which the handicap of blindness imposes on testing methods. Particularly important is the slowness with which blind subjects read. In a study of the influence upon school success of the age at which vision was lost, no positive correlations were established.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

SCIENCE AND SANITY. *An Introduction to Non-Aristotelian Systems and General Semantics. Second Edition. By Alfred Korzybski. Science Press Printing Company, New York.* $6.00. 9¼ x 6; lxxi + 806; 1941.

The first edition of this work appeared in 1933. Since then such advances have been made in Semantics that a revised edition has become inevitable.

It is interesting to contrast this voluminous work with Hayakawa's brief essay *Language in Action* recently reviewed in these columns. The latter writer adheres closely to his text and gives us a highly concentrated solution of Semantics, yet without ever using that term; Korzybski, on the other hand, employs the word frequently but dilutes his discussion with extraneous matter whose relation to the discipline usually associated with the author's name seems somewhat

remote. A peculiar diffuseness of literary expression is the result. Some critics may take exception to this but the average reader who may have only the haziest idea as to what Semantics is all about is likely to find the resultant digressions refreshing.

A clew to the explanation of this form of writing is to be found in Korzybski's own definition of Semantics: "the application of some methods of exact science to the solution of human problems." Such a definition is sufficiently broad to cover practically every field of learning, and the crowded entries in the 18-page index seem to indicate the desire of the author to effect just such a coverage. Korzybski has an encyclopedic mind that recalls that of Karl Pearson, who expanded the last edition of the *Grammar of Science* in the same way. Like Pearson, Korzybski is quite at home in the theoretical abstractions of such scholars as Planck, Einstein, Minkowski, Morgan, Jung, Veblen, etc. (Strangely enough, the name of that almost universal genius, Forel, is lacking from the bibliography of 619 items.)

To the present reviewer it appears that in some respects his work merits adverse criticism. In order to economize on paper and ink (a worthy ambition in these days) the author has had recourse to multitudinous abbreviations, which impede the reader's effort to get the drift of the author's thought. For instance, the term "non-aristotelian" is represented by a capital A surmounted by a macron, and the familiar "etc." gives ground to a combination of punctuation marks whose extensional meaning is likely to evade the reader. It is true that most of these abbreviations are explained in the text, but the explanations are buried in one of the earlier chapters where they are difficult to find when needed.

It is something of a shock to find the ambiguous expression "and/or" sprinkled so lavishly through these pages. These words have different meanings, and the device of so combining them is frequently resorted to by writers who are either uncertain as to which one they mean, or who do not wish to commit themselves irrevocably to either possibility. Neither of these explanations apply here.

Finally, it must be remembered that printed marks on a page are merely symbols of spoken words addressed to the ear, which can apprehend them only one at a time. The meaning of vocal sounds depends on the order in which they are apprehended, and the printed symbols must follow the same order if they are to convey the same meaning. (Our practice of saying "eighteen" and writing "18" is not an exception, for "18" is not a phonetic but an arithmetic symbol.) A monodimensional scheme is not adequate to the complexity of Korzybski's thoughts, and he finds it necessary to introduce at times a vertical relationship in addition to the more familiar horizontal one between pairs of words. His symbols are addressed to the eye, not the ear, consequently the book should not be read aloud, and is not intended to be. The author is of course the best judge as to how his thoughts may be most clearly represented on the printed page, but in this case he has resorted to a device among whose results is an inevitable increase in esotericity.

Finally, a word is needed to explain why vengeance for the evils of modern civilization should be visited on Aristotle. The philosophy of Aristotle is essentially one of dichotomy. The universe consists of such opposed entities as motion and rest, force and matter, time and space, and body and soul. But modern physicists tell us that motion and rest are relative, not mutually exclusive, states; that force and matter are merely manifestations of a single underlying reality; that time and space are not separate continua but different dimensions in the same continuum; and while the synthesis of body and soul cannot yet be demonstrated it may be accepted as an article of faith. One wonders what the response of the Stagirite would be if he could read this book.

THE BOYLSTON STREET FISHWEIR. *A Study of the Archaeology, Biology, and Geology of a Site on Boylston Street in the Back Bay District of Boston, Massachusetts. Papers of the Robert Peabody Foundation for Archaeology. Volume II.*

By Frederick Johnson in collaboration with Henry C. Stetson, Frances L. Parker, William J. Clench, and others. Published by the Foundation, Phillips Academy, Andover, Massachusetts. $2.00. 9¾ x 6¼; xii + 212 + 13 plates + 1 folding map; 1942 (paper).

It is pointed out in the introduction that the term "fishweir can only be used as a convenient name for this assemblage of vertical stakes and horizontal brushwood" found in an area of about two acres lying roughly 30 feet below the present level of the Back Bay region of Boston. The top 18 feet of the area consists of sand and gravel added between the years 1856 and 1894 to fill in the marsh and mud flats of the Charles River. The next 13 feet consists first of a top layer of peat, then a layer of silt, a shell layer (4½ feet below the upper peat layer), more silt, then at a depth of 13 feet another shell layer in which first appear the tops of the stakes of the Fishweir. At varying levels below this—2 to 5 or more feet—is found a lower peat layer and an underlying bed of blue clay in which the lower ends of the stakes are embedded.

That the Fishweir was built by human hands there can be no doubt; also, that it was built when the sea level was considerably below its present level there can be no doubt. It is estimated that more than 50,000 stakes, sometimes placed in groups and sometimes singly, with horizontal bundles of brushwood forming the side walls, were used in its construction. At present no attempt to place the date of the construction of the Fishweir is made but from certain evidence it is quite possible that it was built sometime previous to 3,000

B.C., at about which time it is estimated that the land commenced to submerge. The presence of the Fishweir first became known in 1913 when excavations were being made for the Boylston Street Subway.

The present study is divided into three parts: (1) The excavation of the Fishweir; (2) Analysis of materials from the building excavation. This includes mechanical analysis of the sediments and the identification of foraminifera, mollusks, oysters, diatoms, identification and physical condition of the stakes and wattles of the Fishweir, chemistry of ancient beech stakes, pollen analysis of the lower peat layer and of the silt, and the tentative dating of the deposits; (3) A discussion of the implications and significance of the data from the building excavation.

The text is accompanied by many fine photographic plates illustrating details of the excavations, microscopic examinations of stakes, diatoms, pollen, etc., and figures showing geological deposits, plan of Fishweir, and pollen profiles. Much data is given in tables concerning the occurrence of different species of plant and animal life in the sediment and in an appendix the construction of modern fishweirs is discussed in order to throw light on this ancient structure. (Modern techniques in the study of ancient wood have so far advanced that Baily and Barghoorn, in their discussion of the stakes and wattles of the weir find good evidence for their statement that "the weir appears to have been constructed and repaired during the spring.") A bibliography of 67 titles is also included.

SCIENCE FOR THE PROSECUTION.

By Julius Grant. Chapman and Hall, London. 15s. net. 9½ x 5½; vi + 302; 1941.

This is a semipopular but nevertheless scholarly treatment of the methods used in criminological work. It will appeal to the intelligent general reader, the lawyer, and those having to do in a professional way with physics, chemistry and pathology. Each chapter is provided with a reading list for those who wish more information on any particular phase of the subject.

Grant has provided an interesting introductory chapter on the scientific approach to crime in which he discusses forensic science laboratories in England and the need for a National Medico-Legal Institute.

Minor criminals however, have minor objectives; it is the major criminals who hunt the biggest game, and their methods are entirely different. From the scientific point of view they may be specialists in their own sphere, and by continual study they may so perfect their technique as to become the foremost experts in the science of their own particular 'line'. Such cases therefore, must be dealt with by experts of equal standing on the other side of the fence, and in the past at any rate, it has not infrequently happened that such counter-experts have not been immediately available.

Nearly a third of the book is devoted to a discussion of optical methods of investigation with special chapters on ultra-violet rays, infra-red rays, spectroscopy, X-rays, and the microscope and camera. Combinations of these methods frequently yield remarkable results, as in the following example: fibres of certain paper appear identical when examined under the microscope or when stained or treated by chemicals. However, the use of filtered ultra-violet light in conjunction with the microscope will make it possible to ascertain whether the same combination of fibers is used in one paper as in another.

No attempt has been made to deal exhaustively with chemical methods in use in criminology but an interesting general discussion of the subject is given and many examples of crime detection are explained. The section on blood group tests and serum analysis gives the latest results in this field of research and define clearly the uses and limitations of the tests in problems of heredity and disputed paternity. Finally, the rôle of the psychologist in criminology is discussed. The author here is thoroughly aware of the opportunities which are opening up in this field of approach and many of the attendant difficulties. It is his belief that an important rôle for the psychologist is in the advice which he may give as to the nature of the punishment, this being based on a study of the mentality of the offender rather than the crime which he committed.

THE HISTORY AND EVOLUTION OF SURGICAL INSTRUMENTS.

By C. J. S. Thompson with a Foreword by Chauncey D. Leake. Schuman's, New York. $8.50. 10¾ x 6¾; 113; 1942.

This interesting survey, by the curator of the Royal College of Surgeons, is based on the collection of surgical instruments that had been accumulated within the halls of the institution's building. This structure was largely destroyed by Nazi bombing in the spring of 1941 and little now remains of the once priceless collection of instruments. Fortunately some accounts had previously been published and Thompson had already prepared much of the present volume, so that there is now preserved a complete record of the famous collection which depicted in so remarkable a manner the development of the technique of surgery from the earliest known records down to modern times.

It is not until the Roman period, at the beginning of the Christian era, that the actual instruments used by surgeons are found. Chiefly we know of the instruments of earlier periods through descriptions given by classical authors and representations in marble and stone. The earliest known representation of the scalpel is on a sculptured tablet of stone (date probably 300 B.C.), yet Thompson says that "the cutting knife or scalpel . . . was probably the earliest instrument used

by the surgeon." Roman scalpels frequently embraced two instruments in one—a scalpel at one end and a scoop or spoon at the other. They were usually entirely of metal and the "handles of some of the Roman instruments are often finely worked and occasionally damascened with silver." Handles of wood and bone appeared about the 14th century. After Lister's time the all metal surgical instrument returned.

In the first century of the Christian era we have the first description, by Aulus Cornelius Celsus, of the amputation of a limb. The knife, judging from specimens found at Pompeii, was probably like a large scalpel with a steel blade and bronze handle. Many illustrations are given in the book of amputation knives, from the early straight blade through a whole series of curved (concave and convex) blades to the time of Liston (1794–1847) who established the use of the long straight blade (14½ inches long and 1½ inches deep). Although the saw as used in surgery passed through many different types "no radical change has been made in the saw used in amputations, and it still remains very similar in shape to the tool employed in ancient times."

In addition to the chapters on the scalpel, the amputation knife, and the saw, there are sections on the trepan, vaginal dilators and speculum, head saws, forceps (artery and dressing), bullet-forceps and extractors, instruments for phlebotomy and venesection, trocars, and operating tables. The volume is handsomely printed and illustrated and is provided with a general index.

THE MEN WHO MAKE THE FUTURE.

By Bruce Bliven. Duell, Sloan and Pearce, New York. $2.75. 8¼ x 5⅝; xiii + 325; 1942.

In this book, written for the general public, the author, a journalist not a scientist, sets out to demonstrate that the scientists more than any other group are the men who make the future and are in a position to rescue civilization, if they only will. Why, he asks, has the body of scientific knowledge, for all the changes it has wrought in the fabric of everyday life, thus far made so little impression on the course of human destiny? It is suggested that a beginning of the application of science to the affairs of the world be made even if it is on a small scale only.

The material for the book was acquired by visiting numbers of research laboratories all over the country and interviewing people actively engaged in various kinds of research. While the greater part of the book is concerned with giving a survey of the more recent and exciting discoveries in the fields of genetics, physiology, chemistry, physics, astronomy, medicine, etc., considerable attention is given to the men themselves and their attitudes towards civilization and its problems.

Mr. Bliven states that he found the scientists on the whole rather optimistic regarding the future. They do not believe that civilization is perishing but rather on the threshold of a new and better existence. Men must soon realize how foolish it is to kill each other for the acquisition of raw materials and natural resources which can be produced easily and abundantly in the laboratory. In one chapter we are given a glance at this world of tomorrow when the many products of the laboratory are brought into the practical realm of every day life.

The book is written in an interesting style and should appeal to the layman interested in the achievements of science but who neither has the time nor the technical knowledge required for reading the many scientific periodicals. Portions of the book have already been published in the *New Republic* and *The Reader's Digest* and have no doubt been widely read.

AN ENGLISH 13TH CENTURY BESTIARY. *A New Discovery in the Technique of Medieval Illumination.*

By Samuel A. Ives and Hellmut Lehmann-Haupt. H. P. Kraus, New York. $1.85. 10¼ x 7⅞; 45 + 8 plates. 1942.

The subject of this book is a Latin manuscript copy of *Physiologus*, now the property of H. P. Kraus of New York. Its illustrations have been pounced.

Pouncing was a method of mass production of illustrations before the invention of printing. The illustration to be pounced was perforated by pin pricks along the lines of its pattern, and then placed against white parchment. Powdered charcoal was then rubbed over it, penetrating the perforations and so transferring the design to the parchment.

The pin pricks in the pattern of each illustration perforate through the following illustrations, indicating the pouncing was done after the book was bound. Since each illustration bears the pounce marks of the previous ones, it follows that the reproductions could not have been made directly from the originals, but that the pounced copy was the master stencil. The application of charcoal would have ruined the hand-colored illustrations, and the latter show no indications whatever of such treatment.

The text pages are not perforated, which seems to indicate that they were not part of the book when the pouncing was done. The present binding is therefore not the original. The author's study has led him to believe that the binding dates from the 15th century, the text from the 13th, and that the illustrations are still older, and were separately bound when the pouncings were made.

Photographic reproductions of some of the original figures and of one page of text add much to the interest and value of this work, which consists of a description of the original manuscript and a discussion of its probable lineage and its relationship to 16 other *Physiologus* manuscripts.

ADVENTURES IN SCENERY. *A Popular Reader of California Geology.*

By Daniel E. Willard. The Jaques Cattell Press, Lancaster. $3.00. 9¾ x 6¾; 438; 1942.

This volume may be best classified as a popular reader of California geology. In it the author has gathered together the results of many scientific investigators, interpreted them and presented them in a non-technical form simple enough to interest the general reader. Geology of the western coast, not only of California but of adjacent regions, lends itself easily to such popular treatment.

The story of California is complicated. The real history goes back through the geologic ages. All that is now before us is the product of what has gone before. The rugged mountains, the splendid canyon gorges, the gold washed from stream beds or dug from hard rock veins, the broad expanse of the great Interior Valley, the fields and fertile valleys in which are grown the marvelous variety of farm crops, fruits, vegetables, and nuts, . . . all are the product of the great geologic laboratory which is now called California. The geological story is long. Time has been long. California as we now see it is the product of a long past.

After a discussion of the principal geologic features and the processes involved in producing the varied coast line, mountains, valleys, deserts, fertile lands and the exceedingly varied climate, etc., the author in a section entitled "Geology from a motor car" devotes considerable space to a "Guide for tourists." Eight auto tours are outlined which take in most of the points of particular scenic interest.

The many photographs and drawings add interest to the text. A bibliography, a glossary and an index are included.

SCIENCE AND MAN. *Twenty-Four Original Essays by Aleš Hrdlička, Reinhold Niebur, Jacques Maritain, Alfred E. Cohn, Arthur H. Compton, Harold C. Urey, et al. Edited, with an Introduction and Conclusion by Ruth Nanda Anshen. Harcourt, Brace, and Company, New York.* $4.00. 8½ x 5½; viii + 494; 1942.

Often during periods of upheaval, an uneasiness on the part of thinkers concerning the pass to which mankind has come is reflected in statements on the vagaries of human thought and in programs to set it on the right tract. It is not surprising, therefore, that the present volume should appear at this time. Twenty-four leaders in modern science have contributed original essays to a discussion of the place of science and its achievements in the world of man and have endeavored to point out the paths to be followed if science is to be man's servant rather than man's master.

Among the contributors are Aleš Hrdlička, the brothers Compton, the late Bronislaw Malinowski, founder of a school of the science of man, Julian Huxley, Walter B. Cannon, to mention a few of the more outstanding. The essays are divided into groups such as Science and the universe; Science and society; Science and internationalism; Science and the individual, etc.

An introductory chapter and a conclusion are contributed by the editor, Mrs. Anshen. This volume is the second in the Science of Culture Series. The book is well indexed.

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